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STUDY OF ADVANCED TECHNOLOGY ON JAPANESE NATIONAL RAILWAYS

Prepared for:

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Transportation Development Centre

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17. Abstract

A team of Canadian railway specialists, including representatives from B.C. Rail, Canadian National, and Canadian Pacific, visited Japan for two weeks in the Spring of 1983 to study advanced technology on Japanese National Railways (JNR). Specifically they studied robotics, mechatronics, microcomputers, computer simulations, computer information systems, track recorder cars, freight car classification yards, train monitoring systems, train braking systems, train surveillance equipment, fuel and energy conservation measures, new rail metallurgy and microprocessor-driven devices. They found that JNR was quite advanced in its technical development of track recorder cars, passenger train monitoring systems, train braking research, experimental train surveillance equipment and new rail metallurgy, and recommend that Canadian railways obtain further information from JNR in these areas. In addition, they recommend that Canadian railways and JNR exchange information and possibly set up co-operative projects in the areas of robotics, microcomputers and computer information systems.

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17. Résumé

Au printemps de 1983, une équipe d'experts ferroviaires canadiens, formée de représentants de B.C. Rail, du Canadien National et de CP Rail, ont effectué une visite de deux semaines au Japon, afin de se rendre compte des techniques de pointe utilisées par les Chemins de fer nationaux japonais. Ils se sont notamment intéressés aux secteurs suivants: la robotique, l'électronique appliquée aux procédés mécaniques, les micro-ordinateurs, les simulations assistées par ordinateur, l'informatique, les voitures d'auscultation de la voie, l'informatisation des gares de triage, les systèmes de contrôle des paramètres de fonctionnement, les systèmes de freinage, les systèmes de contrôle et de surveillance des trains, les mesures d'économie de carburants et d'énergie, la nouvelle métallurgie des rails, et, enfin, les dispositifs commandés par microprocesseur. Ils ont constaté la grande avance prise par les Japonais dans les domaines des voitures d'auscultation de la voie, de l'expérimentation du contrôle et de la surveillance des trains, de la recherche des systèmes de freinage, des systèmes de contrôle des paramètres de fonctionnement des trains passagers et de la metallurgie des rails. Ils ont donc recommandé que les compagnies ferroviaires canadiennes se renseignent davantage auprès des chemins de fer japonais concernant les secteurs mentionnés et que, en outre, Canadiens et Japonais procèdent à un échange d'information et peut-être aussi au lancement de projets conjoints, notamment dans les domaines de la robotique, des micro-ordinateurs et de l'informatique.

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SUMMARY

0.1 INTRODUCTION

A team consisting of 5 railway specialists from BC Rail, CN, CP and Maughan Railway Consulting Services Inc. visited Japan from March 28 to April 11, 1983 to study the use of advanced technology on the Japanese National Railways and other related industries. The objective of the study was to identify those technologies that might improve the operations of Canadian railways. The study was undertaken for Transportation Development Centre (Transport Canada) and performed by the Railway Association of Canada and Maughan Railway Consulting Services Inc.

The team studied the following specific areas of advanced technology: robotics, micro computer simulations, computer information systems, track recorder cars, freight car classification yards, train monitoring systems, train braking systems, train surveillance equipment, fuel and energy conservation measures, new rail metallurgy and microprocessor-driven devices. The details of their findings, conclusions and recommendations are included in this report. A brief summary of the conclusions and recommendations is given in this section.

0.2 APPLICATION OF ROBOTS IN JNR AND OTHER RELATED INDUSTRIES

Research work has been done in JNR on the application of robots, but to date a robot is only being used to paint railway car trucks (bogies). Studies are being done in JNR on applications in maintenance areas. It has been difficult for them to find suitable places to apply robots because of the variety and low volume of work. With the research work done on the application of robots in CN and CP, it might be beneficial if CN and CP were to exchange their findings with JNR. It is expected that the application of robots will be slow as this technology has not been found readily adaptable to railway type operations.

0.3 USE OF MICROCOMPUTERS IN JNR

Because of the amount of research work being done in the use of microcomputers in signaling at JNR, it might be useful to have qualified people in this speciality verify JNR's development in this area. JNR is not planning to use microcomputers in the offices to help with office automation. They have elected to eventually go with a centralized system in providing computer capability in offices.

0.4 USE OF SIMULATION IN JNR

The work being done on simulations in JNR has been concerned with high speed passenger trains (Shinkansen) operating under very consistent conditions as to speed, train length, weight, double track and passing sidings. This type of simulation is not applicable to Canadian operations which deal with far more complex operations. If JNR were to undertake simulation of their narrow gauge single track operations, they could progress more rapidly if they reviewed existing Canadian simulation work.

0.5 COMPUTER INFORMATION SYSTEMS IN JNR

The scope of application of computer information systems is broad in JNR and parallels most Canadian railway systems. Because of the limited time available in meetings to discuss this subject, it was not possible to obtain details, especially on the extent of the applications from day to day management, and the integration of the various dependent systems. If a follow up investigation is made in this area, considerable time should be budgeted to discuss this subject with JNR specialists.

0.6 TRACK RECORDER CARS

JNR is quite advanced in the use of track recorder cars for measuring track geometry and converting these measurements through computer analysis to work orders to correct track defects. In addition, they check through subsequent measurements by the track recorder car, whether the work outlined in the work order has been correctly carried out. There would be considerable benefit to Canadian railways in obtaining detailed information on all aspects of JNR's track geometry train technology.

0.7 AUTOMATED CLASSIFICATION YARDS IN JNR

JNR has done considerable work to develop hump yards that provide continuous control of the speed of cars being classified, as opposed to intermittent control that has been the practice in Canadian and U.S. hump yards. For continuous control JNR uses linear induction motors, screw boosters, car pushers and the Dowty system. These devices add considerably to the cost and complexity of hump yards and would not be suitable in Canadian snow conditions.

JNR's new freight policy is to concentrate on unit trains and container trains and to eventually phase out traffic that requires handling through classification yards. It is expected that JNR will curtail any further development of new hump yards and of some of the innovations they have introduced in their most recent designs.

0.8 DEVELOPMENT AND APPLICATION OF ON-BOARD TRAIN PERFORMANCE INSTRUMENTATION

The application of technology for on-board diagnostic purposes in freight service is less developed than our own, whereas passenger service is more extensive than in North America from the limited opportunity we had to become familiar with it. In terms of train control and signalling, JNR appeared to be well advanced with an effective automatic train control (ATC) system which includes cab signalling in place on the entire Shinkansen route and their Yomanote commuter line in Tokyo. Also all JNR trains and lines have been equipped with Automatic Train Stop System since 1966, which will override the driver in the event of violation of a signal. These systems might be investigated further if a particular railway plans to upgrade its present system for automatic control.

0.9 RESEARCH ACTIVITIES RELATING TO IMPROVED TRAIN BRAKING PERFORMANCE UNDER ADVERSE WEATHER CONDITIONS

Composition brake shoe performance investigations undertaken by the JNR under both simulated and naturally occurring adverse weather conditions is a subject area which warrants further dialogue, exchange of information and possibly a follow-up visit. Acquisition of sample JNR anti-snow type shoes should be arranged and performance evaluation of the shoe be integrated with existing testing of conventional and experimental shoe types under the umbrella of the Canadian Railway Association of Canada Train Braking Research Program.

0.10 AUTOMATIC DIAGNOSTIC EQUIPMENT FOR TRAIN SURVEILLANCE

JNR has developed devices to detect wear of wheel flanges, measure wheel back gauge, wheel diameter and detect abnormal vibration arising from flat spots on wheels. The devices might be investigated further for possible application in Canadian railways.

0.11 FUEL AND ENERGY CONSERVATION MEASURES

71.4% of all passenger train km and 76.5% of all freight train km on JNR in 1981 occurred on electrified territory. Thus energy conservation efforts on both JNR and the Japanese private railways are directed principally to their electrified operations. From the standpoint of Canadain railways which operate wholly on diesel fuel there would be no benefit in pursuing fuel and energy conservation with JNR.

0.12 RAIL WEAR AND METALLURGY

As both new rail steels NHH and NSII are being or shortly will be evaluated under Canadian environmental conditions, no further action is recommended at present. Rail research activities should, however, be monitored as it is considered that the Japanese are in the forefront of new rail technology development.

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APPENDIX L102	- Study of Automated Car Inspection
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APPENDIX L104	- Nippon Sharyo - Guide of Toyokawa - Warabi Plant - Nippon Sharyo Seizo Kaisha Ltd. - Profile
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1. INTRODUCTION

The Japanese National Railways (JNR) have had a very outstanding history of sound research in the latest technologies that could be applied to railway operation, and the application of the technologies to their operations. Most noteworthy of the applications are the Skinkansen high speed passenger trains, the Maglev work on the Miyazaki Test Track, and electrification of the major part of Japanese railway operations. All this work has been widely published in various professional journals. In addition, significant advances in the use of new technologies based on computers, micro-electronics and robotics are being made by Japanese industries to improve operations.

In order to appreciate the application of these technologies in Japan, and to examine the possible application in Canadian railways, a team of Canadian railway specialists was sent to Japan to study the application of the advanced technology on the Japanese National Railways, and other related industries. The visit was made under the aegis of the Canadian/Japanese Science and Technology Consultations, the framework permitting exchange and R&D cooperation between Canadian and Japanese organizations in areas of mutual interest. Before this visit, cooperation with Japan in guided ground transportation under the Science and Technology Consultations had been limited to non-contact high speed magnetically levitated systems. One of the objectives of the visit was to identify potential cooperative R&D projects in conventional railway systems. The report deals with the areas that might be considered for such cooperative projects.

The work was carried out under two shared-cost contracts with the Transportation Development Centre - one with the Railway Association of Canada and a second with Maughan Railway Consulting Services Inc. The team was composed of five members - four of which were fielded under the Railway Association contract and the fifth under the latter contract. The members of the Study Team were:

C. Bach	- System Manager, Operations Research and Industrial Engineering, CN Rail
A.E. Bethune	- Director, Technical and Operations Research, CP Limited
R.G. Maughan	- V.P., Maughan Railway Consultants Services Inc.
V.W. Shtenko	- Chief Engineer, B.C. Rail
D. Welsh	- Manager, Financial and Systems Planning, Mechanical Dept. CP Rail

The overall objective was to ensure that Canadian railways are knowledgeable of the best possible systems for railway operations. The project objective was to study advanced technology on Japanese National Railways and identify those systems that could improve operations in Canadian railways. Specific areas that the team planned to study included: robotics, mechatronics, micro computers, computer simulations, computer information systems, track recorder cars, freight car classification yards, train monitoring systems, train braking systems, train surveillance equipment, fuel and energy conservation measures, new rail metallurgy, and microprocessor driven devices.

To achieve the objectives, the team carried out a literature survey of the specified subject areas before making the visit to Japan. The agenda for the visit was prepared by the International Department of JNR. After arrival in Japan some changes to the agenda were made by the Science and Technology office of the Canadian Embassy.

The visit covered the period from March 27 to April 11, 1983. The first week was spent predominantly with JNR at technical meetings and visits to their facilities. During that week a short visit to the Ministry of Transport was included. The second week was spent visiting related industries and several private railways. These visits included Nippon Sharyo Seizo Kaisha Ltd. (Japan Rolling Stock Mfg. Co. Ltd.) in Toyokawa City, Toyota Auto Manufacturing in Toyota City, Hitachi Ltd. in Hitachi, Technova in Tokyo, Tieto Rapid Transit Authority in Tokyo, and Chichibu Tetsudo Railway in Kumagaya. Organizations visited, during both weeks, people whom the team met, purpose of each visit, and the dates of the visit have been detailed in Appendix 1.1.

During these meetings and visits considerable information was given to the study team. Some of it related to the specific areas the team planned to study, and other information was of a general nature. Other information was gathered during the library research done prior to the visit to Japan. Specific information related to the technical areas studied has been included in this main report. General information has been included in a library appendix that has been placed in the libraries of B.C. Rail, CN, CP and TDC. The library appendices are prefixed with an L when referred to in the report. Slides were taken and will be used at various presentations by the study team. These slides will eventually be available from the slide libraries at B.C. Rail, CN, CP and TDC.

The following report deals with the specific technical areas the study team undertook to study and evaluate. The areas include:

2. Application of Robots in JNR and other Japanese Industries.
3. Use of Microcomputers in JNR.
4. Use of Simulations in JNR.
5. Computer Information Systems in JNR.
6. Track Recorder Cars.
7. Automated Classification Yards in JNR.
8. Development and Application of On-Board Train Performance Instrumentation.
9. Research Activities Relating to Improved Train Braking Performance Under Adverse Weather Conditions.
10. Automatic Diagnostic Equipment for Train Surveillance.
11. Fuel and Energy Conservation Measures.
12. Rail Wear and Metallurgy.

Each section covers the technical information that was gathered, and the conclusion the team made as to the level of advancement of that specific technology compared to the development in Canadian railways. Where applicable, recommendations are given if the team thought it advisable to obtain more information or whether cooperative R&D programs might benefit JNR and Canadian railways.

JNR is a complex railway system that operates under certain conditions set by the Government of Japan. For a better understanding of its operation, reference can be made to their 1982 Edition of Facts and Figures included in Appendix 1.2. For information on how JNR fits into the overall transportation system reference could be made to the facts sheets called "Present Situation of Japanese Railways" given to the study team by the Ministry of Transportation and contained in Appendix 1.3.

2. APPLICATION OF ROBOTS IN JNR AND OTHER JAPANESE INDUSTRIES

2.1 Discussion

In examining the application of robots in JNR the team met with people from the Rolling Stock Department of JNR, and the Railway Technical Research Institute of JNR. In addition, to gain a broader perspective of robotic application, we visited the Tieto Rapid Transit, Nippon Sharyo Seizo Kaisha Ltd. (Japan Rolling Stock Mfg. Co. Ltd.), Toyota Motor Corporation, Hitachi, and Technova and had useful discussion with appropriate personnel from each of those organizations.

In Japan, robotic application covers a very broad area from mechanical loading and transfer devices to completely automated machines and programmable manipulators. We were particularly interested in a more restrictive area, and this was limited to that area that is usually accepted as robotic application in North America. To clarify what we conceive as a robot, the definition of a robot according to the Robot Institute of America is:

"A reprogrammable, multi-functional, manipulator designed to move material, parts, tools, or specialized devices through a variety of tasks."

The basic components of a robot generally consist of a manipulator (arm), controller (brain), actuator (mechanism drive), power supply (energy source) and the end of arm tooling (chosen for a very particular function). Pamphlets from two Japanese manufacturers of such devices are contained in Appendix L101.

2.2 Application of Robots in JNR

The first application of a robot in JNR was made in 1975 when it was used at the Nogoya repair operation for painting the exterior of tank cars. The experiment was successful, but JNR personnel said they would have to re-evaluate whether it would be practical to apply a robot again in a similar situation. In 1979 a robot was applied in the Nagaro shop for painting trucks (bogies).

Considerable research on robots has been done at the Railway Technical Research Institute of JNR. Up until 2 years ago, they were fairly pessimistic on robot applications, but with the new robots that have become available recently, they are now more optimistic on future applications. They felt that robots could be used for car overhaul work, particularly in dismantling, assembly, welding, painting and grinding. Where volumes of work are high, robots might be applied, but these areas of high volume work are generally hard to find in JNR. There is also some apprehension on the part of the maintenance staff on the reliability of robotic installations.

Specific applications they are working on at this time include:

- Assembly of brake pads on disk brakes.
- Cutting out corroded panels of freight rolling stock, and rewelding new panels.
- Disassembly and assembly of traction motors.
- Disassembly and assembly of trucks for freight cars.
- Painting of passenger cars.

JNR has set up a committee to study robotic applications that includes representatives from University of Tokyo, manufacturers and themselves. The manufacturers include Fujotso, Fannak, Kawasaki, and Hitachi. Technova is coordinating the work of this committee, and gave us a recent copy of a report of the committee. The original report was in Japanese and when translated will be found in Appendix L102.

2.3 Teito Rapid Transit Authority

The Japanese Ministry of Transport and the Science and Technology counsellor at the Canadian Embassy in Tokyo made arrangements for the study team to visit Teito Rapid Transit Authority. TRTA is a very progressive subway operator, and is responsible for the major portion of the subway lines in Tokyo. We discussed many aspects of their operation including the application of robots. Details on their operation are in Appendix L103.

Although TRTA have studied robotic applications in their operation, to date they have only found one useful application. This has been in the painting of trucks (bogies). They have no plans in the near future for other robots in their operations.

2.4 Nippon Sharyo Seizo Kaisha Ltd.

JNR made arrangements for us to visit Nippon Sharyo Seizo Kaisha Ltd. (or Japan Rolling Stock Mfg. Co. Ltd.) Toyokawa-Warabi works in the city of Toyokawa. This is a modern locomotive and railway car manufacturing plant. They also do research into transportation concepts such as monorail and more recently the VONA system, which is a rubber tired, completely automated light guideway transit system. Details on the firm's operation can be found in Appendix L104.

This plant has 2 welding robots that are of similar design. The welding head is mounted on an arm that can move perpendicular to and along the bridge on which it is mounted. The bridge moves up and down between two columns, thus giving the head the 3rd direction of freedom. The work to be welded is held in a fixture that can be rotated. A computer controls the X.Y.Z. co-ordinates of the welding head, and the rotation of the fixture.

The two welding robots were not in operation when we visited the plant. The people said that the robots were not used that extensively because the work being handled in the plant was not of high enough volume to justify setting up the robots. They said that they had studied possible application of robots in their plant, but for now

could not see any additional applications. However, the 5 numerically controlled metal cutting machines were very useful, especially compared to the 2 welding robots.

2.5 Toyota Motor Corporation

JNR had made arrangements for us to visit the Toyota Tsutsoni Plant near the city of Toyota, because of our interest in robots. We discussed robotics with Mr. Isao Taniguchi, Manager, Public & Community Relations for Toyota, and visited the body building plant and the assembly plant. Toyota started automobile production in 1937 and by the 1st March 1983 had produced 4 million cars. They also have 10 plants consisting of 5 truck and engine plants and 5 assembly plants. They have 3 R & D laboratories. For further general details, see Appendix L105.

Toyota introduced the first robot into their operations 10 years ago and now has 1000 robots. They have limited the types and makes of robots. They have found that robots can be easily reprogrammed to accommodate model changes that occur every 3 years. Robots have been particularly useful in undesirable and hazardous working environments such as painting and welding. The quality of work of robots is higher and very consistent, particularly in the spot welding operations. Although the robot is only 50 to 75 percent as productive as a human operator, it can be justified as it is capable of working 2 or more shifts a day. We questioned them on this statistic and they confirmed that their robots do not work as fast as manual operation. They are not planning to robotize many of their operations, as this would not be cost effective.

In the body welding plant, there are 800 workers and 300 robots. 400 workers are on one shift. We observed a completely automated spot welding line. The spot welding is done by Kawasaki Uni-Mate robots. A picture of this robotic line is on page 6 of the Toyoto brochure that is included in Appendix L105. The price of a robot on this line was 10,000,000 Yen, or about $50,000 Canadian. A manual spot welding line parallels the automated line. Our guide stated that they are not planning to convert the manual line to a robotic operation.

The automatic spot welding line had no people working on it, but close to it was a maintenance area where 5 men sat and waited while the automated line was operating. When the plant was shut down for the coffee break, the automated line was shut down also. The men in the maintenance area immediately went to work on the automatic spot welding line as soon as it was shut down. Our guide could not verify if these men maintained all the equipment in

that area or just the automated spot welding line. However, it does raise the question that automated and robotic operations, although capable of operating without any people, require maintenance, and in most cases, a much higher level of maintenance than machinery operated by people. They said that 50-60 people in total are required to maintain the robots.

We did not see the robots in the painting section, but were taken to the final assembly lines, where there were no robots employed. We asked them if they planned to introduce robots on these lines and we were told that these operations did not lend themselves to robotic operations.

2.6 Hitachi Ltd.

Arrangement for visiting Hitachi Ltd. was made by ourselves, as CN was already working with Hitachi on the application of robots in metal spraying operations, in grit blasting the inside of cylindrical hopper cars, and painting the interior of these cars. We said that we were interested in seeing robots in operation as opposed to the manufacture of their line of robots. They made arrangements for us to visit their electric motor manufacturing facility at their Yamate factory in the city of Hitachi. Details of their operations can be found in Appendix L106.

This factory makes 800 electric motors per month - predominantly traction motors for transit vehicles and diesel locomotives. The plant is 70 years old, but is very well maintained. However, the machinery in it is very modern, including 6 welding robots, 16 numerically controlled machines, a completely automated shaft cutting machine and an automated coil winding machine. The shaft cutting machine not only turns the shaft to tolerances, but measures the shaft before putting it on the completed shaft conveyor. The automated coil winding machine makes 40 percent of the coils required.

The robots in this plant are used for welding large motors of the traction motor size. They use two types. The first is made by Moditom, and is the bridge type described earlier in the section on Nippon Sharyo Seizo Kaisha Ltd. The second type is the manipulator arm type. Hitachi personnel said they have no problems maintaining the robots as the manufacturers make visits every 3 to 6 months to maintain the robots. Hitachi do the programming and the teaching of the robots themselves. They use magnetic tape to store the programs of these robots. The quality of work produced by the robots strictly depends on how well they are programmed. However, once the robot has been set up properly, the quality remains consistent, especially compared to manual welding. The loading of the

work was done by an operator who usually loaded 2 robotic welders. The practice of multiple machine operation was used with numerically controlled machines, where one man would load and unload 2 to 3 machines.

The manager of motor production, engineering section, said they were very happy that robots are now able to do a lot of the traction motor welding, as it is becoming increasingly difficult to obtain skilled people for manual welding. Also, robotic welding has greatly reduced the possibility of eye damage that can occur in manual welding operations. Because the robots can work continuously, they said they were able to get more productivity from a robotic welder than a manual operation.

The practice of cleanliness that predominates Japanese life was very apparent in this plant. All areas were exceptionally clean. In some of the manufacturing departments, we removed our shoes and put on slippers before entering the departments. These departments were doing what would be considered normal manufacturing with no requirement for sterile atmospheres. Such clean working conditions gave these departments a very pleasant and homelike environment.

After the visit to the electric motor manufacturing plant, we were shown their heavy machinery and assembly plant. Here they manufactured large machines such as hydraulic generators in the order of 1 million H.P., steam turbines and generators of the order 1 megawatt power, and large atomic research equipment. Their largest horizontal boring machine has the capability of machining a piece 30 meters in diameter. The buildings are serviced by 500 and 300 ton cranes.

2.7 Conclusions

Information gained during these visits with JNR, Teito Transit Authority and Nippon Sharyo Seizo Kaisha Ltd. (Japan Rolling Stock Mfg. Co. Ltd.) has confirmed our recent research in the application of robots for railway operations. Equipment maintenance areas are where robots have the most promise for use. However, the variety and low volume usually makes it difficult to find an operation that can be economically replaced by a robot. Even in the manufacture of new rolling stock, application of robots has been difficult because of the low volume of work. High volume manufacturing operations as at Toyota and Hitachi showed how effective robots can be in spot welding, arc welding, and painting.

Research in the application of robots is being done at JNR, CNR and at CP. It would be beneficial if these railway organizations would exchange their findings with

each other so as to progress the search for areas where robots can be effectively used to lower costs of railway operations. It is expected that the application of robots will be slow as the technology has not been found readily adaptable to railway type operations.

3. USE OF MICROCOMPUTERS IN JNR

3.1 Discussion

Mr. Sasake, Chief Researcher for the Signal Lab at the Railway Technical Research Institute described their use of microcomputers in JNR. He said most of the labs at the Institute use microcomputers in their work. In signalling, they have used various types of systems. This includes 2 out of 3 voting systems, 2 out of 2 voting systems, and A and B type systems. They are doing extensive research in setting up reliable microcomputer systems for signalling operations.

As far as using microcomputers in offices, JNR has looked into various stand-alone microcomputers, but has decided not to employ such computers. They prefer to go to completely integrated systems where terminals would be available to users for their computer requirements. In this way, any computer work done locally can be integrated into their overall information system.

We had an opportunity to see Japanese microcomputers at a microcomputer show in the Fukoku Seimei Bldg. underground shopping area. The computers on display were similar to Apples, IBM-PC's and TRS80's. The displays on the monitors were in Japanese lettering and arabic numerals. For a complete personal computer system, i.e. computer, monitor, 2 floppy disc drives and printer, they gave us an approximate price of 20,000,000 Yen or $10,000 Canadian. This is comparable to similar systems in Canada.

3.2 Conclusions

Study Team members were not qualified to assess JNR's use of microcomputers for signalling operations. Because of the amount of research being done in the use of microcomputers in signalling at JNR, it might be useful to have qualified people in this specialty to verify their development in this area. In the use of microcomputers for the office environment, development in Canadian railways is much further advanced. We use the microcomputer in offices to help with office automation. In JNR, they have elected to eventually go with a centralized system in providing a computer capability in offices.

4. USE OF SIMULATIONS IN JNR

4.1 Discussion

Dr. Sato, the Chief of the Transportation Systems Laboratory at JNR Technical Research Institute showed us the computer simulation that they developed for the Shinkansen train operation. This simulation involves double track operation, with each track restricted to one way operation. Two types of passenger trains are operated. The first is called Hikari and makes only 6 stops in 1069 kilometers. The second is called Kodama and makes 27 stops in the same distance. The simulation gives a tool to develop new schedules and operating rules in the event the system is shut down for an emergency and requires to be restarted.

By simulation they were able to recommend a change in the operating rule after the shutdown of the system. Instead of restarting all the trains after a shutdown in the same order of operations as prior to the shutdown, they proved that less train delay will result if the express trains are returned to service first, with the local train held in the stations for a longer period. In this way, the total train delay of the express plus local trains is minimized.

Shinkansen train scheduling appeared to predominate most of their simulation work at this time. Up to 1980, their group was called the Operations Research Laboratory, but now they are called the Transportations Systems Laboratory. There are 5 O.R. analysts at the JNR corporate planning division who get involved with capital decision planning.

In our presentations, we explained the work that is being done at CN on simulations of hump yards, flat yards, single track, and bi-directional double track, intermediate signals, container and piggyback terminals, car availability planning, empty car flow forecasting, fuel consumption forecasting, motive power main shop scheduling, warehouse design, Matane Ferry and cash flow. They showed considerable interest in this type of simulation work.

4.2 Conclusions on Use of Simulations

The work being done in simulations in JNR is not too applicable to Canadian operations. Their simulations are concerned with high speed passenger trains operating under very consistent conditions as to speed, train length, weight, double track and passing sidings. If they were to get into simulating their narrow gauge single track operations, hump and flat yards, and container terminals, they could progress more rapidly if they reviewed some of our existing simulations.

5.0 COMPUTER INFORMATION SYSTEMS IN JNR

5.1 Discussion

On March 29th the study group met with Mr. Kazuo Nagai, Deputy Director of the Information Systems Department, and Mr. Yukio Kimura, Senior Researcher, Information Systems Laboratory, Railway Technical Institute of the JNR. The meeting lasted approximately 40 minutes, during which some technical papers were distributed and very briefly discussed. Practically all that follows in this report has been gleaned from a reading of these papers after our return to Canada.

5.2 Passenger Reservation Systems

Rail passenger systems are large scale operations on the JNR. The table following summarizes the different versions of the MARS reservation system. Of special note are the following:

(i) the understanding of the study group was that specific seats and not just open space in a car were always reserved.

(ii) MARS 150 reservations can be made from any push button equipped phone without agent involvement.

(iii) the huge volume of reservations handled.

MARS - Capacity and Current Performance

	MARS 105 Regular	MARS 150 Telephone	MARS 202 Groups
Capacity per day 000's	1,000	20	600
Number of terminals	1,800	400,000	150
Passenger per reservation	Max. 14	Max. 4	Max. 980
Sales during FY 1980 000's	134,000	50	42,000

5.3 Freight Service Reservation Systems

The Freight Operation Control System (FOCS) and the Effectual Planning and Operation of Container Systems (EPOCS) provide freight service reservations. Customer applications for service appear to be accepted for processing up to 1 week in advance. Both systems appear to check equipment availability and could reject a request on this account. In the case of regular freight services (FOCS), the system appears to do some additional capacity checking - i.e. "confirmation and reservation of shunting capacity at the origin and destination stations as well as

the transfer capacity of the marshalling yards". These systems are suggestive of a degree of operational scheduling that exceeds current Canadian practices.

These systems also appear to handle customer shipment status enquiries, and they can produce advance delivery notices (1 day before arrival) to consignees.

The following table summarizes the services.

FOCS	EPOCS Regular Service	Container Service
Agent Sets	220	480
Trains Handled	300	routes 3,000
Cars Handled	6,000/day	containers 15,000/day
Service Hours	8:50 - 20:30	6:00 - 24:00

5.4 Yard Classification Systems

This subject is more thoroughly addressed in another part of this report dealing in general with freight car classification systems. Suffice it to say here that current JNR yard information systems appear to have little to offer the Canadian experience. There is however one area of research and development that may hold future promise. It is automatic car identification (ACI), a problem that has obvious relevance to yard operations.

In the late 1960's the JNR experimented with and rejected two ACI technologies.

- scanning laser beam - optical technology
- electromagnetic induction coupling

The first failed due to difficulties in cleaning dirt, and the second due to the transponder's cost.

Since 1979 a new method using passive "tags" and 2.45 GHz wayside microwave excitation has been under study.

The main functional requirements are summarized below and may be of interest to Canadian railroads:

(1) 12 digit car ID for up to 120,000 cars
(2) passive tag - no batteries, no cleaning, no tuning
(3) car speeds up to 130 km/h
(4) tag height of 1m $\pm$ 0.5m above rail
(5) wayside antennas 2.1 to 4.4m from track centre
(6) - failure rate to obtain ID less than 1 in 100,000
    - mistaken ID rate negligibly small
(7) full range of climates, MTBF of 10 years.

The current state of this development and prognosis for the future is not known.

5.5 Computer Aided Traffic Control

This JNR system is called COMTRAC. During the course of the visit several references to it were made. From these verbal references it was inferred that COMTRAC performed two main functions.

- integration with CTC in controlling day-to-day Shinkansen train movements.
- as a planning or simulation tool for assessing the aggregate train delay resulting from a hypothetical disruption to Shinkansen service and a user supplied "solution".

In these two applications it addresses a homogeneous group of trains running uni-directionally on double track. Therefore it may be of limited direct value to Canadian railroading.

Based on the papers distributed, COMTRAC also apparently allocates Shinkansen cars to trains taking into account inspection programs, is a communication system for transmitting directives, transmits information to stations for announcements and departure sign posts, and generates statistical reports on Shinkansen operating performance.

5.6 Shinkansen Management Information System

In many respects the JNR treats the Shinkansen service as a stand-alone service from all the narrow gauge operations. An example of this approach is their SMIS system which addresses equipment, facilities and electric power distribution, but only for the Shinkansen.

SMIS appears to integrate information which typically is addressed by separate systems - eg. provides maintenance history data on main car components such as trucks, automatic train control, etc. on the one hand, and provides rail maintenance data on the other hand. The typical North American approach would be to address these types of data in two systems - one for the Mechanical Department and one for the Engineering Department. One could speculate that the JNR approach has something to do with the special nature and organization of the Shinkansen service - in other words a total systems approach to planning and managing the service.

Following is a table of functions addressed by SMIS.

Management of Rolling Stock	Management of Facilities	Management of Electric Installations
1. Provides car allocation planning data.	1. Directs rail maintenance and confirmation.	1. Provides trolley wire abrasion measurement data.
2. Provides data on car services, operation performances and analysis of mechanical failures.	2. Directs long rails check and provides work data.	2. Provides trouble-shooting reports an irregularities analysis data.
3. Reports maintenance data and provides car conditions data.	3. Generates rail maintenance plans and provides analytical data.	3. Provides maintenance history data.
4. Reports check and replacement of specified equipment and supplies.	4. Provides inspection analysis data on rail maintenance supplies (rails, turnouts, expandable joints, etc.)	4. Provides data on actual power supply and demand.
5. Provides maintenance history data on main components (trucks, ATC, etc.).	5. Provides rail maintenance data.	5. Performs automatic diagnosis of wireless equipment on the train.

5.7 Kosaku Information Control System (KICS)

KICS is a network of 6 subsystems for managing 28 narrow gauge equipment workshops. The 6 subsystems are:

(i) car history
(ii) personnel - ie., probably payroll, staff records, etc.
(iii) supplies - ie., inventory control and probably purchasing
(iv) workshop accounting - ie., from verbal references it appears to be a standard cost system
(v) work management - ie., probably production scheduling
(vi) facility management - ie., probably maintenance and scheduling of shop machines

On the surface, this appears to be a very comprehensive management system. Unfortunately, what is not known about this and other JNR systems is the true nature of the integration of these areas. Is it a high level single data base system, or simply a matter of one system producing some tape input to another system on another computer?

In North America, Manufacturing Resource Planning (MRPII) systems integrate many such functions - ie., production scheduling, purchasing and inventory control, cost accounting, facility utilization, etc., but MRPII approaches have not yet been applied to the rail industry. In Canadian railways such integration as does exist for managing work shops is of a fairly low level. Lack of detail information from the JNR makes comparisons difficult.

5.8 Supplies Management System

The study group was interested but unsuccessful in determining what approaches to demand forecasting, replenishment timing logic, and order sizing logic were being utilized in this system. Of particular interest was whether statistical time-series forecasting/order point/economic order quantity was used, or a more advanced approach such as material requirements planning.

All that is known is that inventories are kept at many locations, that the larger locations distribute material to the smaller ones, and that purchasing is somehow integrated with inventory control.

5.9 Other Systems

In addition to the above mentioned systems there is a range of accounting, personnel and statistical reporting systems typical of North American railroading experience.

5.10 Conclusions

(i) The scope of application systems is broad, encompassing most Canadian railway systems and including some other areas such as freight reservations not presently addressed.

(ii) A significant degree of integration is suggested by the distributed papers but the exact nature and quality of the integration is unknown.

(iii) The variety of computer equipment suggested in the papers, and the vintage and capacity of some of the models suggests the integration between systems is not advanced.

(iv) The sparsity of computer equipment on most shop floors and offices visited suggests a lesser role for the applications in day-to-day management than might be inferred from the papers.

(v) Any follow-up investigation in this area should budget significant time to obtain the details. Communications in this subject area were more difficult than most other topics.

6. TRACK RECORDER CARS

6.1 Discussion

Track recorder cars (geometry car or train) are used extensively on all lines, namely standard gauge (Shinkansen Lines) and narrow gauge. On the Shinkansen Lines the track geometry car is primarily a train of 12 cars which closely approximates the weight and size of a regular Shinkansen passenger train (16 cars).

We saw the track geometry train while at the Shinkansen Shops in Tokyo and had an opportunity to see the onboard equipment. It was indicated that the track geometry train not only measures track parameters, but it also provides necessary measurements related to the catenary system and power supply. Testing on the Shinkansen Lines is done every 10 day, while on the narrow gauge lines the frequency varies between 2 to 6 times a year depending on density of traffic. The type and configuration of track geometry train for the narrow gauge lines was not observed or discussed. It was not determined what criteria was used to develop the 10-day testing interval other than the maintenance contractor is paid on the basis of the results provided by the track geometry train.

The track geometry train is fully computerized, with the parameters supplied to the main depot for processing, with

hard analog copies available on the train. See Appendix 6.1 for details on the process. In addition, the data are recorded on tape for storage and future analysis. It should be noted that spots or areas found by the inspection train to have deviation values worse than the target maintenance values listed below are immediately repaired. On the next inspection operation (within ten days) the results of the repair are examined by the inspection train, and if the irregularities are within the target maintenance values the main line contractor is paid (maintenance is carried out under contract).

Target Maintenance Values

Type of Track Irregularity	Logitudinal Level mm (over a 10 m stretch)	Alignment along 10 m chord	Circularity at curve mm (on 10 m chord)	Gauge mm	Cross Level mm	Torsion mm/2.5 m
Target values for good riding quality	7	4	5	+6 to -3	5	5*

* (from Japanese Railway Engineering, Vol. 19, No. 2, 1979 titled "History and Future Outlook of Track Maintenance of Shinkansen").

Based on discussions held with JNR Research Institute officials, a computer system has been designed for management and maintenance of rails, bridges, buildings and electrical installations. Details covering these systems are not available.

6.2 Conclusions

On the basis of observations made and discussions held, there appears to be potential benefit in obtaining additional detailed information on all aspects of Track geometry train technology and computerized maintenance systems. It appears that Japanese track geometry train technology can be applied to the Canadian needs.

7.0 AUTOMATED CLASSIFICATION YARDS IN JNR

7.1 Discussion

Since the completion of the first hump yard in 1968 at Koriyama, 6 hump yards have been built in JNR with variations in design features. The Study Team had an opportunity to discuss these design features with engineers from the Railway Technical Research Institute. Also, we saw the operation at Shiohama Yard where linear induction motors are employed. Information was gathered on these hump yards and is included in Appendices L108 to

L111. Short descriptions will be given of the various interesting features and further details are available in the appendices. Some of the pamphlets are in Japanese, but are sufficiently pictorial that the system can be understood.

7.2 Koriyama and Musachino Hump Yards

The first hump yard installed was Koriyama Marshalling Yard, 182 KM northeast of Tokyo, and is partially automated. The automation is applied to control the descent of the car into the classification yard. Classification track switches do not appear to be controlled automatically. A second yard of similar design was built in 1979 just on the outskirts of Tokyo and called the Musachino Yard. This yard has automatic control of the movement down the hump to the classification tracks, setting of the classification track switches and information processing for control of general information in the yard. This operation would be fairly similar to our existing hump yard operations in North America. Cars that are humped are controlled by multi-stage car retarders after humping to lower the speed so that the car will couple at a low enough speed to prevent damage, but will not stall before coupling to the preceding car on that track. This type of system is called intermittent control. Further details are contained in Appendices 7.1 and 7.2.

7.3 Takasaki Hump Yard

In 1970, the Takasaki Hump Yard, which is 150 KM north of Tokyo, was built with the Dowty system to control the speed in the classification tracks to a constant 5 KM/hour. This type of yard controls the speed of the cars from release to coupling. JNR found this continuous control system very suitable for humping the light cars used by JNR except it tended to be noisy.

7.4 Shiohama Hump Yard

The next yard with continuous control was built at Shiohama Yard about 50 kilometers south of Tokyo. Here they use the linear induction motor in the classification yard tracks and a retarder just below the hump. Information on this yard is given in Appendices 7.3, L107 and L108. The yard has a capacity of 3000 cars a day, but is now handling about 1200 cars a day. A car is put over the hump, braked by the retarders, and then caught by a linear induction motor. Then the car is either braked or accelerated to a coupling speed varying between 2.5 to 5.00 KM/hr. and then released 50 to 90 meters before the preceding car. Details on the operations, speeds, and distances for release are given in Appendix 7.4.

The linear induction motor car handles up to 10 empty cars, 8 loaded cars, or a maximum of 150 tons. The computer controls the retarder based on weight of car, speed, shape of car, and local wind condition. It controls the linear induction motor so that it accelerates to catch the car smoothly, and then brakes, accelerates, or keeps a constant speed so that the specified coupling speed is reached at the release of car before coupling. The computer also records the distance from the last car in the track to the normal waiting position of the linear motor near the hump end of the classification track.

We observed the operation in heavy rain, and there was no problem with the linear induction motor catching the cars smoothly. The wetness on the reaction plate did not affect the precision of the induction motor. When the cars coupled, very little noise was heard. Compared to our yards, the operation was exceptionally quiet.

For incoming trains, a telex is sent from the previous reporting point up the line about 10 KM away. The train consist is typed at the yard office into a machine that produces a computer punch hole tape. This tape is sent by wire to the hump office about 100 meters away, where a similar machine reproduces the punch hole tape. At the same time, a switch list is produced for the brakeman at the hump. The paper tape is fed into the computer at the hump. As each cut comes up, the hump yard controller can observe the information on the monitor to verify if the automatic system is functioning properly, and if the cars are cut in the correct quantities as indicated on the switch lists. He can manually override the computer setting of the classification tracks.

The classification tracks hold 56 cars, and the maximum length of trains is 55 cars. With 55 cars the trains gross 1200 tons. There are 45 up trains and 45 down trains (i.e. up and down from Tokyo) per day handled in the yard. The yard is owned by JNR but operated by a contractor (Kanagawa Rinkai Railway Co.). JNR brings in mainline trains and hauls out blocked mainline trains. The contractor receives the incoming trains on the arrival tracks and makes up outbound trains on the departure tracks. The contractor also does the local industrial switching of the predominantly petro chemical plants. This is the only yard where a contractor is responsible for yard classification and local pick-up and delivery of cars.

The reliability of the linear induction motors is 100 percent. The yard is shut down each day for two hours for linear induction motor maintenance. In that time, 1 to 2 of the 15 linear induction motors in this yard are inspected and repaired.

The linear induction motors at the Shiohama Yard give continuous control of cars being humped. Such a design would probably be acceptable to handle dangerous commodities that normally are not allowed to be humped. The great disadvantage of the design is the cost, the inability of the linear induction motor to operate in snow, and the necessity for the induction motor to return to its ready position near the hump end of the classification track before another car can be humped into the same track. The operators said this waiting was a distinct disadvantage of the design. The linear induction motor unit is a complex unit, and probably is expensive to maintain. Hitachi made these motors, and could supply further information on installation costs and recommended maintenance schedules.

All switches in the receiving and departures yard are mechanized and controlled from a central traffic control room in the yard office.

7.5 Kitakami Hump Yard

The next two yards built were completed in 1978 and were the Kitakami Yard, about 400 KM northeast of Tokyo, and the Suotondo Yard, near the southern end of the main island Honshu. Both yards used linear induction motors in the classification tracks and screw boosters to accelerate cars after humping.

The maximum design capacity of Kitakami was 2000 cars per day. In addition to linear induction motors and screw boosters, Kitakami had retarders, and Dowty systems in the 2 herringbone tracks. The herringbone tracks can give 7 car classifications in the space normally taken by 3 tracks. Only ten cars can be held in each of the classifications in such a design. Details on the design are given in the material in Appendix 7.5 and L109.

When we visited JNR Shinkansen repair facilities just south of Kitakami, we asked for some information on the operation of Kitakami. We were told that the maximum capacity was 1210 cars per day, not the 2000 cars per day given in one of the attached articles. Traffic was down, and only 850 cars per day were being handled. The Linear Induction motor stopped operating in snow until the snow was cleared. Apparently, the snow plough on the motor and the heating coils are not sufficient to keep it going when it snows. About 210 cars per day were classified at Kitakami for distribution in the Sendai area.

7.6 Suotonda Hump Yard

Suotonda Yard has many features similar to Kitakami Yard, but has some distinct features that make it unique to other hump yards. The information on Suotonda yard in Appendix 7.6 and L110 gives diagrams and pictures that help to explain the design of the yard. This yard has only 12 classification tracks, and 2 sets of herringbone tracks that give 14 more classifications. The unique feature of the yard is that it has a low hump followed by screw boosters that accelerate the car in the event it has not gathered enough speed on the hump. This is different from most hump yards where cars are humped to give them speed and then they are braked down to the speed that they can reach the car that they are to be coupled to, and be coupled at a moderate coupling speed.

Cars for the tracks with linear induction motors are accelerated by screw boosters before they are taken over by the linear induction motors. Cars for the herringbone tracks are accelerated by screw boosters until they reach the herringbone tracks, and can be accelerated further by a series of screw boosters down the centre track. When the car reaches one of the 7 sortation sections, a retarder brakes the car down to a suitable speed for coupling. Only a maximum of 10 cars can be held in any one of the sortation sections in the herringbone tracks.

Unfortunately we did not secure a diagram of the Suotonda Yard to explain how this low hump system worked until we had completed our visit to JNR. Therefore, we did not question JNR on the effectiveness of low hump followed by booster operations as compared with high hump and retarder operations. When we spoke to JNR about the screw boosters they said they work very well. Also they confirmed that the Dowty system works well. The linear induction motor system works well, but is costly, and slows down the operation of humping if cars have to be held because the linear induction motor has not returned to normal waiting position.

The Japanese manufacturers have been quick to come up with designs to overcome some of the unfavourable features of the linear induction motor, by developing a car booster that is run by a cable. One model travels between the rails and another on one side of the tracks. Diagrams and photos of such designs are shown in the pamphlet in Appendix 7.7 and L110. The text unfortunately is in Japanese in these pamphlets. To our knowledge, none of these units are in operation in a hump yard in JNR.

7.7 Conclusions on Classification Yard Development in JNR

JNR had done considerable work to develop hump yards that provide continuous control of the speed of cars being classified, as opposed to intermittent control that has been the practice in Canadian and U.S. hump yards. With intermittent control, cars are humped, then braked by car retarders to reduce car speed for safe coupling. With continuous control, cars are humped, then braked or accelerated, before being caught for speed control by a linear induction motor, and then finally released for coupling. Another system accelerates the car after humping, and then reaccelerates the car several times as it moves down to the final classification track where it can be given a final braking with a retarder.

For continuous control, JNR uses linear induction motors, screw boosters and the Dowty system. They all add considerably to the cost and complexity of hump yard design. In JNR, they have only been used in small yards of the order of up to 20 classification tracks as opposed to our yards that have up to 72 classification tracks. We doubt very seriously if these mechanisms for continuous control could be used in Canadian snow conditions. The complexity of the designs would make it difficult to clear the snow on the classification track area.

JNR announced on Feb. 1, 1983, that it will concentrate on point-to-point shipping of freight cars. This type of traffic will include unit train traffic, container traffic and train loads from one shipper to one consignee. They plan to get out of the traditional yard to yard method of handling freight cars. With this policy, classification yards will eventually disappear. It is expected that JNR will curtail any further development of new hump yards and of some of the innovations they have introduced in their most recent designs.

8. DEVELOPMENT AND APPLICATION OF ON-BOARD TRAIN PERFORMANCE INSTRUMENTATION

8.1 Discussion

The state-of-the-art of on-board train performance and equipment monitoring systems for freight service on Japanese National Railways is less developed than our own. The principal reasons for this are that train lengths are relatively short by our standards, speeds are low, train inspection points are numerous and axle loads are conservative; thus the need for on-board equipment is very limited.

On passenger equipment, particularly on the Shinkansen trains, the preference clearly has been for on-board

systems with the capability for continuous surveillance. With train consists which are fixed and the opportunity for hard wired permanent interconnection links, it has been possible to establish functional and effective on-board systems. On the most recent Shinkansen trains, for example, roller bearings are equipped with fuses which melt under heat distress initiating an alarm in the driver's cab. Similarly it is understood, although we did not observe the unit, that cars are equipped with vibration sensors to detect flat wheels or other sources of abnormal dynamic vibration. Electrial parameters are also monitored on a continuous basis and displayed at the driver's control console.

8.2 Conclusions

The application of technology for on-board diagnostic purposes in freight service is less developed than our own, whereas passenger service is more extensive than in North America from the limited opportunity we had to become familiar with it.

In terms of train control and signalling however, JNR appeared to be well advanced with an effective automatic train control (ATC) system which includes cab signalling in place on the entire Shinkansen route and the Yamanote commuter line in Tokyo. Also, all JNR trains and lines have been equipped with an Automatic Train Stop System since 1966, which will override the driver in the event of violation of a signal. These systems might be investigated further if a particular railway plans to upgrade its present system for automatic control.

9. RESEARCH ACTIVITIES RELATING TO IMPROVED TRAIN BRAKING PERFORMANCE UNDER ADVERSE WEATHER CONDITIONS

9.1 Discussion

It was evident from our discussions with members of the Japanese Railway Technical Research Institute that considerable fundamental research has been undertaken to understand the effects of snow and moisture on brake shoe/wheel interaction.

Basic research in this area began in 1968 and has led to a series of improved anti-snow composition brake shoes. The current prototype shoe is the sixth in this series.

Two basic shoe types have evolved:

1) A dispersion type in which hard particles are randomly dispersed in the composition shoe material

2) An "inserted" or horizontal band variety which is comprised of blocks containing hard particles inserted in the composition shoe material.

While the anti-snow shoes are being used year-round on JNR cars which normally are assigned to the northern snow areas of Japan, research work is continuing in an effort to reduce hollowing wheel tread wear and thermal cracking.

Some preliminary testing has been initiated on sintered shoe materials, however, they are recognized as being initially more expensive and test experience to date indicates more wheel thermal cracking is experienced. The tests are however continuing.

The Japanese indicated that they too had experienced the phenomenon of brake shoe metal pick-up in the presence of moisture and speculated that perhaps water quenches the hot wheel tread creating hard brittle particles which subsequently break off and imbed in the brake shoe surfaces.

In discussing correlation between laboratory climatic test parameters and actual operating conditions, the principal researcher indicated that there had been no effort undertaken to quantify the level of moisture in or near the brake shoe/wheel interface.

JNR research personnel recognize there are compromises that have to be investigated; improved braking performance appears to be coupled to increased wheel wear and thermal cracking. Research is continuing to discover the most effective trade-offs.

Material presented during the visit relating to brake shoe research activities is enclosed in Appendices 9.1, 9.2, 9.3 and 9.4.

9.2 Conclusions

Composition brake shoe performance investigations undertaken by the JNR under both simulated and naturally occurring adverse weather conditions is a subject area which warrants further dialogue, exchange of information, and possibly a follow-up visit.

Acquisition of sample JNR anti-snow type shoes should be arranged and performance evaluation of the shoes be integrated with existing testing of conventional and experimental shoe types under the umbrella of the Railway Association of Canada Train Braking Research Program.

10. AUTOMATIC DIAGNOSTIC EQUIPMENT FOR TRAIN SURVEILLANCE

10.1 Discussion

Application of wayside instrumentation for train/equipment surveillance in Japan is in the embryonic stage.

In the freight sector, speeds are relatively modest, average hauls are limited in length, and the frequency of failure is so low it has not been considered necessary to install hot box detectors or other wayside protective devices.

In the passenger sector, the preference has been for on-board surveillance and warning systems. Wayside instrumentation is used to monitor wind velocity and seismic activity for the Shinkansen routes.

Recently JNR has initiated testing, which is still in the experimental stage, focused on development of a wayside system for the Shinkansen trains to:

1) Detect wear of the pantograph pan (slide plate)
2) Measure the push-up pressure of the pantograph
3) Detect wear of wheel treads
4) Detect wear of wheel flanges
5) Measure the wheel back gauge distance
6) Measure wheel diameter
7) Detect abnormal vibrations in wheels (skid flats)

The initial application of such equipment, once practical use of the system has been confirmed, will be near shops or inspection points with possible mainline installation in the future.

Two items presented at the JNR Research Institute relating to the development of wayside monitoring systems are enclosed in the Appendices 10.1 and 10.2.

10.2 Conclusions

Four applications of possible interest to Canadian railways are summarized in the following tabulation.

Name of Device	Functions	Principles of Operation
Device for detection of wear of wheel flange.	Automatic measurement of cross-sectional profile of wheel flange when car enters or leaves inspection and repair shop.	Irradiates parallel beam on exterior face of wheel from light source situated by the track. Irradiated light spot travels from top of flange to wheel tread as wheel moves on. By receiving the reflection by means of a pick-up tube, a cross-sectional profile is illustrated.
Device for measurement of wheel back gauge.	Automatic measurement of wheel back gauge when car enters or leaves inspection and repair shop.	By means of gap sensors installed inside the track at a given distance, detects the change in inductance due to eddy current produced on inside of wheel and converts the distance between inside of wheel and sensor into electric signals and thus calculates back face gauge.
Device for measurement of wheel diameter.	Automatic measurement of wheel diameter.	Three different transformers installed longitudinally along the rail, calculate wheel diameter by potential difference among transformers as wheel moves by.
Device for detection of abnormal vibrations in wheels.	Detection at wayside of a truck differing in vibration pattern from other trucks of a multiple unit while cars are in motion.	Measures vibration condition of each truck at time of passing through the device by means of an accelerometer placed on a railway tie or through a shear strain gauge pattern applied to the web of the rail.

11.0 FUEL AND ENERGY CONSERVATION MEASURES

11.1 Discussion

Fifty-four percent of all railway route km. in Japan are electrified. On the JNR, all of the Shinkansen lines and 41% of the balance are electrified as are also 86% of all private railway lines. More significantly, 71.4% of all passenger train km. and 76.5% of all freight train km. on the JNR in 1981 occurred on electrified territory. Thus energy conservation efforts on both JNR and the private railways are directed principally to their electrified operations and although keen interest was exhibited in the Canadian presentation "Fuel Conservation on Canadian Railways", little information was provided that would be helpful to ongoing efforts in Canada.

During discussions with JNR technical research officers it was learned that JNR is conducting studies to improve diesel combustion, and that investigations into reduction to engine idle time and engine idle speed are being made. These conservation measures have been examined and already implemented on Canadian railways to the extent that present circumstances permit. JNR also noted the benefit of maintaining a constant train speed in the interests of energy conservation - another measure already well recognized on Canadian railways.

The use of aluminum to reduce passenger car weight was mentioned by JNR and the Teito Rapid Transit Authority. Aluminum alloy extrusions are used extensively by Nippon Sharyo Seizo Kaisha Ltd. (Japan Rolling Stock Manufacturing Co. Ltd.) for underframes of passenger cars for Japan. Aluminum construction is facilitated by the fact that the Japanese test for compression is only 100 tons rather than 500 tons as in North America.

Limited numbers of hopper cars in which aluminum has been employed to reduce weight have been in service on Canadian railways. The first were purchased in the early 1960's. First cost is much higher than for all-steel cars and can only be justified at present under special circumstances such as very high annual loaded mileage or unusual track conditions. Insofar as freight cars are concerned, JNR mentioned only that they employ aluminum in the manufacture of car doors.

As already noted, most rail transportation energy conservation efforts in Japan are, for good reason, directed towards electric traction. To this end, the use of choppers is widespread as are field choppers giving regenerative braking. Other measures include reduction to off-peak substation voltage, variable consists to suit traffic, and the use of microprocessors to optimize

motoring-coasting-braking cycles. A comprehensive paper dealing with these and other measures, by Dr-Eng. Satoru Sone of the University of Tokyo, was published in the January 1983 issue of the Railway Gazette. A copy of that paper is provided as information in Appendix 11.1 of this report.

11.2 Conclusions

It is evident that from the standpoint of the Canadian railways, which operate almost wholly on diesel fuel, there would be no benefit in pursuing this subject further with JNR.

12. RAIL WEAR AND METALLURGY

12.1 Discussion

Rail wear and rail steel metallurgical properties were discussed with research officials of the JNR Technical Research Institute. It was mentioned that 16 tons (versus 29 tons in Canada) is the maximum permissible axle loading on the JNR system and consequently plastic deformation does not occur. The principal rail problems on JNR are gauge corner wear, shelling along the centre line of the rail and on the gauge corner and "high speed" shelling on the Shinkansen lines equipped with 60 kg/metre rail.

To counteract shelling and gauge corner wear problems, JNR is using head hardened rail (60 kg/metre) on curves of radius less than 600 metres and end hardened (100 millimetres) carbon rail on tangent track and in curves of radius greater than 600 metres.

Considerable research and testing has been undertaken to alleviate shelling particularly on the high speed Shinkansen lines. Tests on low carbon (bainitic), medium carbon, and high silicon composition steels did not provide positive results. The program did, however, indicate that a pearlitic micro-structure with small interlamellar spacing is preferable.

Testing has been initiated on the JNR with a new head-hardened (NHH) slack quenched fine pearlitic rail steel which showed encouraging results under test at the AAR FAST Facility. The JNR in-service trials are continuing.

A further improved steel NS II (Cr-Si type), not presently used in JNR track, which is slack quenched and of fine pearlitic micro-structure has been developed. This rail is not used on the high speed Shinkansen lines because of an inherent surface waviness. The high ultimate tensile

strength of the rail (1.3 GPa) does not permit normal roller straightening. This rail has shown extremely favourable results at the FAST test loop.

A comparison of the chemical and physical characteristics of the NHH and NS II rail steels is as follows:

	C	Si	Mn	P	S	Cr	Nb	0.2PS MPa	TS MPa	El %	RA %	Hb
NHH	0.78	0.23	0.88	0.14	0.15	-	-	850	1263	15.7	40.3	372
NSII (NSII Cr-Si type)	0.76	0.82	0.82	0.20	0.006	0.49	.005	902	1324	19	50	-

With respect to Shinkansen lines where the axle load is 15 tons and speeds are of the order of 210 km per hour, it has been observed that shelling commences after the passage of 150 million tonnes. In order to extend rail life, grinding is carried out twice a year and lubricants are applied to prevent excessive gauge face wear.

In connection with fatigue testing, it was indicated that ultrasonic-induction and ultrasonic testing is being carried out. However, the frequency of testing was not provided. JNR Research Institute personnel are continuing laboratory testing of rails using reduced scale wear rigs and rolling contact fatigue machines to improve their understanding of the basic physics of wear and fatigue.

Printed materials relating to Japanese rail steels and new rail developments are provided in Appendices 12.1 and 12.3 which deal with:

> Specificaitons for Steel Rails - May 1981.
>
> Basic Properties of High Strength Rail Steels and New Rail Developments - October 1982 - Nippon Steel Corporation.

In addition a catalogue produced by Nippon Kokan covering technical and dimensional data on rail is in Appendix L111.

12.2 CONCLUSIONS

As both new rail steels NHH and NSII are being, or shortly will be evaluated under Canadian environmental conditions, no further action is recommended at present. Rail performance should, however, be monitored as it is considered that the Japanese are in the forefront of new rail technology development.

APPENDICES

APPENDIX 1.1

STUDY OF ADVANCED TECHNOLOGY ON J.N.R.

MEETINGS AND VISITS

	Date and Location	Persons Present*	Purpose
	March 27 - Tokyo		
1.	President Hotel (10:00 - 11:30 hrs.)	T. Kunita - Manager, Japan, Korea & Taiwan - CNR, Tokyo S. Ashizawa - Senior Sales Rep'ive. - CNR, Tokyo	Familiarization with arrangements made by JNR & CN for travel during mission and for interpreter services.
	March 28 - Tokyo		
2.	Chancery, Canadian Embassy (09:00 - 09:45 hrs.)	J. MacDowall - Counsellor, (Science & Technology) Cdn. Embassy A. Rusinek - First Secretary (Commercial) Cdn. Embassy	Orientation.
3.	Ministry of Transport (10:00 - 11:00 hrs.)	Mr. Hashimoto - Director, General Affairs Div., Rly. Supervisory Bureau Ministry of Transport J. MacDowall - Canadian Embassy	Overview of Japanese transport scene.
4.	Japanese National Rlys., H.Q. International Department (11:15 - 12:30 hrs.)	Kazuo Matsuki - Assistant to the Director International Department, JNR Yoshihiro Kyotani - Director Technical Develop. Dept., JNR Yukio Suzuki - Senior Staff, International Department, JNR	Review of itinerary.
5.	Japanese National Rlys., H.Q. International Department (13:30 - 17:15 hrs.)	Kazuo Matsuki - Assistant to the Director International Department, JNR Yukio Suzuki - Senior Staff, Intern'l. Dept., JNR K. Nagai - Deputy Director Information Systems, JNR Yukao Kimura - Senior Researcher, Information Systems Lab., Rly. Technical Research Institute, JNR H. Soejima - Deputy Director of Rolling Stock Section, JNR Tshuchida - J. MacDowall - Canadian Embassy Hotsumi Harada - Director Intern'l. Affairs Dept. JNR (briefly following conclusion of meeting)	Presentations by Canadian team members.

* In addition to Canadian team members

MEETINGS AND VISITS

	Date and Location	Persons Present*	Purpose
	March 29 - Tokyo		
6.	JNR Shinkansen Control Centres (10:00 - 12:00 hrs.)	Kazuo Matsuki - Assistant to the Director International Dept., JNR Chief Dispatchers - JNR	Explanation of Shinkansen train control systems.
7.	Japanese National Rlys., H.Q. International Department (13:00 - 17:00 hrs.)	Kazuo Matsuki - Assistant to the Director International Dept., JNR Mr. Omori - Manager, Freight Dept., JNR K. Nagai - Deputy Director, Information Systems, JNR H. Soejima - Deputy Director of Rolling Stock Section, JNR S. Matsuyama - Steel & Alloy Lab., Rly. Tech. Res. Inst., JNR	Overview of significant technical developments on JNR.
	March 30 Tokyo		
8.	Shinkansen (Tokaido) Car Maintenance Depot (10:00 - 12:15 hrs.)	Kazuo Matsuki - Assistant to the Director International Dept., JNR Mr. Kawakami - Chief, Tokyo Car Maintenance Depot, JNR Mr. Oikawa - Deputy Chief, Tokyo Car Maintenance Depot, JNR	Overview of Shinkansen (Tokaido) car maintenance system and facilities.
9.	JNR Railway Technical Research Institute (Kunitachi) (14:30 - 17:00 hrs.) NOTE: Unless otherwise noted, all "persons present" are employed at the Research Institute.	Takeshi Sugiyama - Vice-Director Masaru Ishiyama - Ryoichi Masuda - Technical Inform. Centre Makoto Hayashi - Chief, Train Operations Lab. Katsuro Takasawa - Chief, Metallic Materials Lab. Tado Ohyama - Senior Research Engineer Car Braking Lab. Kazuo Matsuki - Asst. to the Director International Dept., JNR Kaname Idumura - Chief Researcher Car Braking Lab.	Overview of Railway Technical Research Institute and viewing of experiments/testing underway in train simulation, rail and brake shoes.

* In addition to Canadian team members

MEETINGS AND VISITS

Date and Location	Persons Present*	Purpose
March 31 - Tokyo 10. JNR Railway Technical Research Institute (Kunitachi) (10:00 - 17:00 hrs.)	Takeshi Sugiyama - Vice-Director Ryoichi Masuda - Technical Information Centre Sawase - Senior Researcher, Machinery Systems Lab Furuki - Senior Researcher, Machinery Systems Lab Yoshihiko Sato - Chief, Track Lab Teranaga - Senior Researcher, Track Lab Nagasquia - Sr. Researcher, Control Engineering Lab Todoroki - Sr. Researcher, Cntrl. Eng. Lab Shioya - Sr. Researcher, Cntrl. Eng. Lab Tanabe - Sr. Researcher, Cntrl. Eng. Lab Makoto Hayashi - Chief, Train Operations Lab Yukio Kimura - Sr. Researcher, Info. Sys. Lab Sasaki - Sr. Researcher, Signalling Lab Dr. Tanaka - Chief, Car Structure Lab Katsuro Takasawa - Chief, Metallic Materials Lab Masayuki Miyamoto - Fellow Research Engineer, Car Dynamics Lab Kaname Idemura - Chief Researcher, Car Braking Lab Tadao Ohyama - Sr. Researcher Engineer, Car Braking Lab Shinobu Yasukaik - Sr. Researcher, Car Performance Lab	Presentations by Canadian Team (1 hr.) Technical discussions for balance of day.
NOTE : All "persons present" are employed at the Research Institute. Regretably, it proved impossible to record the names of many of the institute personnel who took part in the many different discussions during this very interesting day.		
March 31, Tokyo 11. Technova Inc. Fukoku Seimei Bldg. (19:00 - 21:30 hrs.)	Toshikazu Kurokawa - General Manager, Technova Inc Kiechi Oshima - Vice Chairman, Technova Inc. Yoshihiro Kyotoni - Director, Technical Development Dept., JNR Masakazu Igutchi - Professor, Dept. Mech. Eng. Univ. of Tokyo Takehiko Fujioka - Lecturer, Dept. Mech. Eng. Univ. of Tokyo	To discuss progress made with their contract on robotics research.

* In addition to Canadian team members

MEETINGS AND VISITS

	Date and Location	Persons Present*	Purpose
	April 1, Tokyo/Kyoto		
12.	JNR Marshalling Yard (Shiohama) (10:00 - 12:30 hrs.)	Kikuo Arai - Traffic Dept., Tokyo South Rly. Operating Div., JNR - Station Master, Shiohama Marshalling Yard Mr. Koyama - Deputy Stn. Master Shiohama Marshalling Yard	To view automated yard equipment and operation.
	To Kyoto via Shinkansen (Tokaido) Express train at 15:00 hrs. Apr. 1, Departed Kyoto Mon. Apr. 4 via Shinkansen (Tokaido) Local train at 08:21 hrs. Arrived Toyokawa City at 09:55 hrs.		
	April 4, Toyokawa City		
13.	Offices & shops of Nippon Sharyo Seizo Kaisha Ltd. (Japan Rolling Stock Mfg. Co. Ltd.) (10:15 - 13:00 hrs.)	K. Hirai - Director, Chief Engr. Rolling Stock Tech. Dept. Japan Rolling Stock Ltd. Itsu Nagami - General Manager, Export Planning & Eng., Japan Rolling Stock Ltd. Junji Togashi - Deputy Project Mgr., Argentine EC Project, Japan Rolling Stock Ltd.	To ascretain extent and type of robotics employed.
	Taxi to Toyota City		
14.	April 4, Toyota City Toyota Auto Manufacturing Head Office & Tsumi Assembly Plant (14:00 - 15:40 hrs.)	Isao Taniguchi - Manager, Public and Community Relations Akemi Naito - Public and Community Relations	To ascertain extent and type of robotics employed.
	Taxi to Toyokawa City - Shinkansen (Tokaido) Local train at 17:07 hrs. arriving Tokyo 19:28 hrs.		

* In addition to Canadian team members

MEETINGS AND VISITS

Date and Location	Persons Present*	Purpose
April 5, Tokyo/Sendai Subway & commuter train to Omiya. Shinkansen (Tohoku) Express train at 10:00 hrs. arriving Sendai 11:59 hrs.		Overview of Shinkansen (Tohoku) car maintenance system and facilities.
15. Shinkansen (Tohoku) Car Maintenance Depot (14:00 - 17:00 hrs.)	Mr. Urayama - General Affairs Div., Sales Dept., JNR Sendai Mr. Kashimura - Assistant Station Master JNR, Sendai Mr. Yamamoto - Director, Shinkansen Maintenance Depot, Shedai Mr. Yamba - Mgr. General Affairs Shinkansen Maintenance Depot Mr. Oshida - Manager, Inspection Shinkansen Maintenance Depot Mr. M. Wakabayashi - Director of Train Ops. Dept. Mr. Oide - Station Master	
April 6 - Sendai/Hitachi/Tokyo Departed Sendai via JNR passenger train at 09:25 hrs. arriving Hitachi 12:30 hrs.		
16. Offices, electric motor mfg. plant, and turbine generator mfg. plant of Hitachi Ltd., Hitachi (12:30 - 17:15 hrs.)	Hidetoshi Arakawa - Rly. Equip. Dept. Hitachi Ltd., Tokyo Toshiyuki Kondo - Mgr., Motor Mfg. Dept. Hitachi Works Ken-ichi Akaihashi - Mgr., Motor Prod'n. Eng. Section, Hitachi Works Takeshi Yamaguchi - Mgr., Elec'l. Machine Design Dept., Hitachi Works Yukiaki Shimizu - Eng'r., Traction Motor Design Dept. - Hitachi Works Tomoyuki Yoshimare - Assistant Co-ordinator Yamate Business Adm. Section	To ascertain extent and type of robotics employed.
Departed Hitachi via JNR passenger train at 18:03 hrs., arriving Tokyo at 19:50 hrs.		

* in addition to Canadian team members

MEETINGS AND VISITS

	Date and Location	Persons Present*	Purpose
	April 7 - Tokyo		
17.	Technova Inc. Fukoku Seimei Bldg. (10:00 - 12:00 hrs.)	Tsutomu Yasui - Manager, Overseas Operations Technova Inc. Takahiko Fujioka - Lecturers, Dept. of Mechanical Eng., Univ. of Tokyo	To obtain additional information regarding material obtained at meeting March 31.
18.	Teito Rapid Transit Authority Office	Shoji Yanagawa - Ass't. Mgr., Public Relations Section, Teito R.T. Authority Masatochi Ohta - Ass't. to Gen. Mgr. (Foreign Affairs), Teito R.T. Authority Ryochi Yamada - Vice Director, Electricity Dept., Teito R.T. Authority Mr. Kurokawa - Rolling Stock Maintenance Teito R.T. Authority Masahiko Yamagato - Deputy Director, Electricity Dept., Teito R.T. Authority Satoru Miyakawa - Deputy Director, Train Op'ns. Dept., Teito R.T. Authority	To obtain information on operations and maintenance of subway.
	April 8 - Kumagaya		
	Mini-bus at 08:30 hrs. Tokyo to Kumagaya arriving Kumagaya 10:30 hrs.		
19.	Chichibu Tetsudo Railway Kumagaya - Offices & Facilities (10:30 - 16:30 hrs.)	Mr. Kakihara - President Chichibu Tetsudo Rly. Mr. Ishikawa - Managing Director, " " " Mr. Tomoro - Sales Manager, " " " Mr. Ishikawa - Director, Planning, " " " Mr. Gamo - General Manager, " " "	Overview of a private freight and passenger railway operation.
	Return via mini-bus to Tokyo arriving 19:30 hrs.		
	April 9 - 10		
	Tokyo to Nikko and return. No meetings.		

* In addition to Canadian team members

MEETINGS AND VISITS

	Date and Location	Persons Present*	Purpose
	April 11 - Tokyo		
20.	Science & Technology Bldg. Canadian Embassy (09:00 - 09:30 hrs.)	J. MacDowall - Counsellor, (Science & Technology) Cdn. Embassy A. Rusinek - First Secretary (Commercial) Cdn. Embassy	Debriefing of team.
21.	Science & Technology Bldg. Canadian Embassy (10:00 - 12:00 hrs.)	J. MacDowall - Counsellor (Science & Technol.) Cdn. Embassy Yoshro Kawakita - Manager, Japan, CP Rail Russ Steele - Managing Director, Far East and Australia, CN Rail D'arcy McGee - Counsellor, Metallurgy/Minerals Energy Representatives of the following Japanese businesses: Nippon Steel Ltd. Nippon Kokan K.K. (NKK) The Japan Iron & Steel Federation Japan Coal Development Co. Ltd. Sumitomo Metal Industries Ltd. The Federation of Electric Power Companies Nihon Keizai Shimbun Yomiuri Shimbum Keidanren	Presentations by Canadian team members, in response to special request by Mr. MacDowall.

* In addition to Canadian team members

KEY STATISTICS, 1981

Railway Route Length (km)	21,419
Double- and Multi-tracked Sections	5,654 (26.4%)
Electrified Sections	8,435* (39.4%)
Conventional Lines, Narrow Gauge (1,067 mm)	
D.C.	4,965
A.C.	3,470
Shinkansen, Standard Gauge (1,435 mm)	
A.C.	1,069
Railway Stations	5,305
Passenger and Freight	1,036
Passenger	4,149
Freight	111
Length of Bridges (km)	2,362
Length of Tunnels (km)	1,891
Train-km (thousands)	650,603
Railway Traffic Volume (millions)	
Passengers Carried	6,793
Tons Carried	111
Passenger-km	192,115
Ton-km	33,398
Number of Employees	401,362
Revenues & Expenses (million yen)	
Revenues	3,246,106
Expenses	4,331,997

* Excludes the Shinkansen lines.

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EXPLANATORY REMARKS

1. The years in this booklet are fiscal years ending on March 31 of the following calendar year.
   All the figures, unless otherwise stated, are as at the end of fiscal year 1981.
2. In quoting figures, decimal fractions of five and over are counted in most cases as a unit and the rest are disregarded.
   The sum of figures on some items may not coincide with the total given.
3. Conversion rates
   ¥1 (Yen) US$3.70 (As of October 1, 1982)
   1 km = 0.621 mi
   1 kg = 2.205 lbs

REVIEW OF THE YEAR

JNR traffic in 1981 suffered from a near-stagnant economy. Japan's GNP grew by only 2.7%, the lowest since 1974. Most domestic transportation services experienced little or no growth; JNR passenger traffic recorded a slight decrease from the previous year, while rail freight traffic showed a second successive year of sharp decline.

Total domestic traffic by all modes registered 790,500 million passenger-km, up 1.1%, and 427,500 million ton-km, down 2.6%, compared with the previous year. JNR trains (excluding ferry boats and buses) accounted for 192,100 million passenger-km, a decrease of 0.5%, and 33,400 million ton-km, a 9.6% drop. The JNR rail market share was 24.3% of total domestic passenger traffic and 7.8% of freight traffic.

Operating revenues totaled 3,173,000 million yen, a gain of 209,300 million yen, or 7%, over the previous year. Passenger revenue rose because of tariff increases, aggressive promotion of rail travel, and increased subsidies. Freight revenue fell with the decline in freight traffic caused by slow business recovery and competition with other transportation systems.

Despite personnel reductions and other efforts to cut expenditures, operating expenses totaled 4,325,400 million yen, an increase of 361,200 million yen, or 9%, over the previous year. The change was mainly due to significant increases in payments to employees upon retirement, dues to the mutual aid pension fund, and interest on debt. The result was an operating loss of 1,152,400 million yen, and, after incorporating non-operating revenues and expenses, a net loss of 1,085,900 million yen.

ORGANIZATION AND LEGAL STATUS OF JNR

1. Relationship with the Government

The first railway in Japan was opened between Shimbashi (Tokyo) and Yokohama by the State in 1872. Since then the State Railways had grown as a system operated by a Governmental Department until 1949, when the present Japanese National Railways (JNR) was established as a public corporation under the Japanese National Railways Law. The National Government is the sole investor in JNR, which is operated under the supervision of the Ministry of Transport. The Ministry has a Transport Council that advises the Minister.

2 Powers Delegated to and Restrictions Imposed on JNR

The JNR President has full decision-making powers on some aspects of JNR management, while for others, the permission or authorization of the Minister of Transport is required. Basic passenger and carload freight rates can be revised within prescribed limits with the approval of the Minister of Transport; otherwise, approval of the National Diet is required. For revision of passenger and freight charges authorization of the Minister of Transport is sufficient. Some other important matters requiring approval of the Minister of Transport are:

(1) Construction of new railway lines and acquisition of private railways or other transportation operations.

(2) Operation of new ferry lines or new motor transport services related to JNR's railway service.

(3) Closure or suspension of service on a line.

(4) Major projects, such as electrification of railway lines, that are stipulated under Ministry of Transport Ordinances.

On minor operating matters, final decisions are made by the President, but on important matters, by the JNR Board; the President is the Chairman of this Board.

JNR is authorized to operate:

(1) The railway enterprise and related activities.

(2) Ferry services and related activities in connection with the railway enterprise.

(3) Motor transport services and related activities in connection with the railway enterprise.

(4) Pipelines whose pipes are primarily underneath land used for the railway enterprise, and related activities.

(5) Facilities for power generation and transmission and electric communication necessary for providing the above services.

(6) Other related necessary business activities.

JNR also may perform certain services for others if these services are related to land transport and do not interfere with normal operations: manufacture, repair, inspect or procure machines, tools and other commodities; carry out construction work; manage business activities; or conduct technical experiments and research.

JNR is required to have its activities inspected by the Inquiry & Audit Board, whose members are appointed by the Minister of Transport.

TARIFF SYSTEM

The Japanese National Railways Tariff Law amendment in December 1977 authorized JNR to determine its basic passenger and carload freight rates with only the approval of the Minister of Transport, provided that upward tariff revisions allowable will be limited to covering the increment in expenses caused by the rise in commodity prices. For revisions beyond this limitation, approval of the National Diet is required. This amended law became effective from March 31, 1978 and is to remain in force until the extinction of JNR's accumulated deficit, excluding the debt shelved.

1. Passenger Rates

The two-zone tapering-distance scale for ordinary fares was changed to three zones in May 1979. Rates per km were raised by an average of 5.5% in April 1980, 9.5% in April 1981, and again 6.7% in April 1982.

Ordinary Fare Rates per Kilometer

Zone / Effective	Up to 300 km	301–600 km	Over 600 km
May 1979	¥10.70	¥ 8.55	¥4.70
April 1980	11.35	9.05	4.95
April 1981	12.40	9.90	5.40
April 1982	13.25	10.55	5.75

(2) Elimination of new ferry lines or new motor transport services related to JNR's railway service

(3) Closure or suspension of service on a line

(4) Major projects, such as electrification of railway lines, that are stipulated under Ministry of Transport Ordi-
(ces.

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Commutation pass rates vary with the type, validity period and traveling distance; in recent years discounts applying to commutation travel have gradually been reduced. JNR is authorized to set charges, such as those required for use express trains, berths and "Green Cars" (cars with supe accommodations), with the approval of the Minister of Trans-port; these were not changed in 1979 but were raised in 1980 and 1981.

2. Freight Rates

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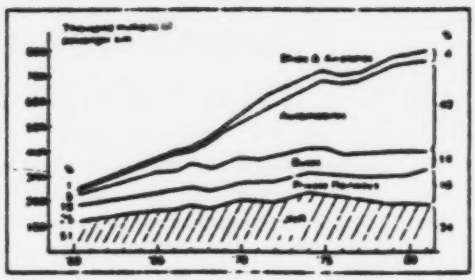
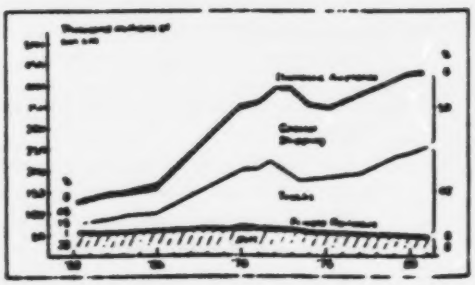
After national economic trends and competition from other modes were taken into account, carload rates were raised by 9.8% on the average in April 1980, and containerload rates by 6.7%. They were raised again by an average of 9.9% each in April 1981, and in April 1982 by 6.8% and 6.4% respectively.

DOMESTIC TRAFFIC AND SHARES OF VARIOUS MODES OF TRANSPORT

Shares of Various Modes of Transport in Passenger Traffic



Shares of Various Modes of Transport in Freight Traffic



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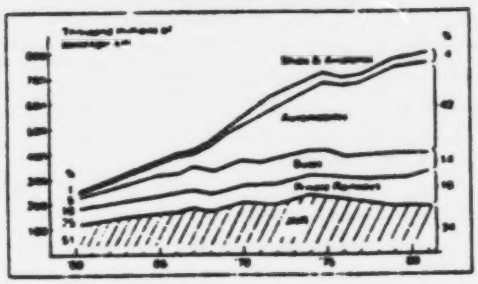

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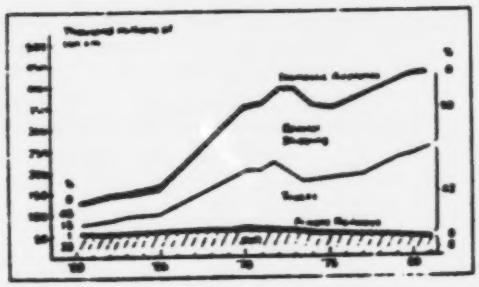


PASSENGER SERVICE

1. Passenger Traffic

Domestic passenger traffic for fiscal year 1981 by all modes amounted to 790,500 million passenger-km, only 1.1% over the previous year, reflecting stagnant economic conditions and personal spending. Of this total, JNR carried ordinary passengers for 113,800 million passenger-km and commuters for 78,300 million passenger-km, totaling 192,100 million passenger-km.

Shinkansen traffic remained almost the same as in the previous year, with the help of promotional efforts to increase passenger revenue, especially from visitors to the Portopia exposition in Kobe.

Traffic by limited and ordinary express trains on the conventional lines declined 3.8% from the previous year, largely because of expansion of the express highway network and increases in jet aircraft flights to local airports. Lines in Hokkaido reported a small increase, however, when the Sekisho line was opened to provide more direct service to the Kushiro and Obihiro regions.

Electric train services in metropolitan areas showed an increase of 0.8% for ordinary passengers and 1.3% for commuters.

Passenger traffic on local lines -- lines other than trunk lines, and outside of metropolitan areas -- decreased 5.3% from the previous year. These lines account for 45% of JNR route length, but their 9,500 million passenger-km in 1981 was only 5% of the system total.

Passengers Carried

(millions)

Year	Ordinary		Commuter		Total	
1975	2,558	100	4,490	100	7,048	100
1977	2,509	98	4,560	102	7,068	100
1978	2,444	96	4,553	102	6,997	99
1979	2,392	94	4,539	101	6,931	98
1980	2,376	93	4,448	99	6,825	97
1981	2,348	92	4,445	99	6,793	96

Passenger-Kilometers

(millions)

Year	Shinkansen		Conventional lines				Total	
			Express train		Local train			
1975	53,318	100	52,990	100	108,981	100	215,289	100
1977	42,187	79	46,655	88	110,810	102	199,653	93
1978	41,074	77	44,244	83	110,526	101	195,844	91
1979	40,986	77	43,301	82	110,403	101	194,690	90
1980	41,790	78	42,407	80	108,947	100	193,143	90
1981	41,717	78	40,784	77	109,614	101	192,115	89

Note: "Express train" includes both limited express and ordinary express trains.

2. Passenger Revenue

JNR passenger revenue amounted to 2,309 thousand million yen, an increase of 7.7% over the previous year. This reflects the April 1981 increase in passenger rates and JNR efforts to increase revenue through sales campaigns and promotional fares, such as the Full Moon Pass for older couples and the Japan Rail Pass for foreign tourists.

Passenger Revenue

(thousand millions of yen)

Year	Ordinary passengers		Commuters	Total	
	Shinkansen	Conventional lines			
	473	608	148	1,081	100
	610	873	240	1,723	160	
	5	939	264	1,849	171
	02	1,043	320	2,055	190
	722	1,069	352	2,143	198
	781	1,139	389	2,309	214

Average Traveling Distance per Passenger

(km)

Year	Ordinary		Commuter		All passenger average		Shinkansen	
1975	54.5	100	16.9	100	30.6	100	339	100
1977	48.6	89	17.1	101	28.2	92	333	98
1978	48.1	88	17.2	102	28.0	92	332	98
1979	48.4	89	17.4	103	28.1	92	331	98
1980	48.5	89	17.5	104	28.3	93	333	98
1981	48.5	89	17.6	104	28.3	92	332	98

3. Traffic in Metropolitan Areas

The number of passengers carried by JNR in the Tokyo metropolitan area increased slightly in 1981, after several years of small declines, private railway and subway traffic continued to increase. In the Osaka metropolitan area, both JNR and private railways continued to show reductions in the number of passengers carried, while the subway system again showed an increase. The JNR share of the total number of railway passengers in 1981 was 40% in Tokyo and 22% in Osaka.

As a general tendency, metropolitan area traffic rises to show peaks during office and school commuter hours, causing severe congestion. This congestion was eased to some extent on Tokyo's Sobu line and in other places through improvements to increase capacity. In Osaka, the congestion rate showed a declining tendency on most lines, accompanying the traffic decrease, the Katamachi line was an exception to this trend.

Railway Passenger Traffic in the Tokyo Metropolitan Area

(Daily average in thousands)

Year	JNR		Private railways		Subways		Total	
1975	10,343	100	9,230	100	4,789	100	24,382	100
1977	10,577	102	9,546	103	5,030	105	25,153	103
1978	10,577	102	9,756	106	5,039	105	25,372	104
1979	10,527	102	9,822	106	5,086	106	25,435	104
1980	10,379	100	10,000	108	5,487	115	25,866	106
1981	10,424	101	10,163	110	5,625	117	26,212	108

Railway Passenger Traffic in the Osaka Metropolitan Area

(Daily average in thousands)

Year	JNR		Private railways		Subways		Total	
1975	2,458	100	6,488	100	2,074	100	11,020	100
1977	2,481	101	6,403	97	2,047	97	10,921	99
1978	2,446	100	6,445	99	2,084	100	10,975	100
1979	2,391	97	6,287	97	2,095	101	10,773	98
1980	2,303	94	6,069	94	2,184	105	10,555	96
1981	2,282	93	6,042	93	2,262	109	10,586	96

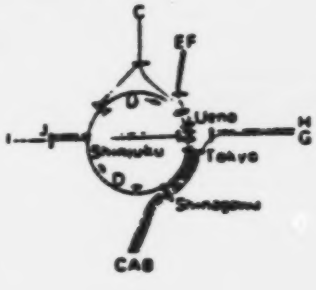
Notes: 1. The figures for each mode of transport indicate ordinary ticket and commutation pass users combined.
2. Tokyo and Osaka metropolitan areas refer to an area 50 km in radius from Tokyo Station and Osaka Station respectively.

Train Operation during Rush Hours in the Tokyo Metropolitan Area

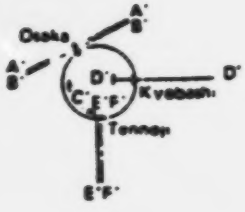
(As of November 1981)

Route	Line	Train consist (cars)	Load factor (%)	Headway
A	Tokaido	15	225	3'30"
B	Yokosuka	15	223	5'30"
C	Keihin Tohoku	10	252	2'30"
D	Yamanote	10	233	2'30"
E	Joban (Rapid service)	10	274	6'00"
F	Joban (Local service)	10	247	3'20"
G	Sobu (Rapid service)	15	231	4'00"
H	Sobu (Local service)	10	244	2'40"
I	Chuo (Rapid service)	10	258	2'10"
J	Chuo (Local service)	10	185	3'00"

Tokyo Metropolitan Area



Osaka Metropolitan Area



Train Operation during Rush Hours in the Osaka Metropolitan Area

(As of November 1981)

Route	Line	Train consist (cars)	Load factor (%)	Headway
A	Tokaido (Rapid service)	11–12	208	7'30"
B	Tokaido (Local service)	7	209	4'20"
C	Osaka Loop	8	228	3'00"
D	Katamachi	6	252	4'00"
E	Hanwa (Rapid service)	6	251	5'00"
F	Hanwa (Local service)	6	201	5'00"

3. Computerized Seat Reservation System

For better service to travelers, MARS 202 was introduced to deal exclusively with party and group travelers, supplementing MARS 105 that had been at work since September 7, 1972 for individual reservations.

Central processing unit	No. of Green Windows	No. of computer terminals at ticket windows	No. of superior trains covered by computer (per day)	No. of seats covered by computer (per day)
MARS 105	781	1,590	1,675	498,460
MARS 202	-	159	2,037	456,755

FREIGHT SERVICE

1. Freight Traffic

JNR freight traffic in 1981 totaled 33.4 thousand million ton-km, a decline of 9.6% from the previous year. Tons carried, 110.57 million, were down 9.1% from the previous year and 21% below the level in 1979. This significant decrease is due largely to stagnant manufacturing activity, cold weather damage to crops and intensified competition from other modes of transport. Revenue from freight traffic decreased by 5.6% from 1980 and by 12.1% from 1979.

Freight Traffic

Year	Tons carried (millions)	Index	Ton-kilometers (thousand millions)	Index	Daily average ton-km (millions)	Revenue (thousand million yen)
1975	142	100	46.6	100	141	231.9
1977	132	93	40.6	87	127	286.6
1978	133	94	40.4	87	125	297.7
1979	136	96	42.3	91	116	340.9
1980	122	86	37.0	79	101	317.6
1981	111	78	33.4	72	92	299.8

(1) Principal commodities

The top four commodities, oil, limestone, cement and coal, accounted for 49.24 million tons carried, a decline of 6.8% from the previous year. Other noncontainerized commodities totaled 52.09 million tons, showing a large decrease of 11.6%.

Tonnage Carried by Commodity

(thousands)

Commodity	1980	1981
Oil	16 500	16 055
Limestone	15 343	14 598
Cement	14 986	13 823
Coal	5 891	5 783
Total (A)	52 720	49 239
Chemical fertilizer	5 367	4 517
Chemicals	3 885	3 430
Ore	3 913	3 256
Paper	3 194	2 947
Rice	2 999	2 770
Feed	2 873	2 275
Pig iron & steel	2 368	1 963
Alcoholic beverages	1 509	1 383
Timber & lumber	1 588	1 103
Motor vehicles	749	676
Pulp	697	619
Gravel & sand	478	316
Fresh fruits	322	240
Fresh & frozen fish	196	174
Other commodities	29 826	26 380
Total (B)	58 944	52 089
(A) + (B)	111 664	101 328
Containerized cargo	9 956	9 244
Total all freight	121 619	110 572

(2) Containerized Freight

Container traffic decreased by 7% to 9,244 thousand tons and 5% to 7,788 million ton-km compared with the previous year. The decrease in short distance traffic was greater than that in middle and long distance movements, and the decreases in housing materials, chemical products and paper products were particularly notable. As in the case of other freight traffic, these declines were largely due to weakness in industrial activity and competition from other modes, such as trucks.

Container Traffic

Year	Tons carried (thousands)	Ton-kilometers (millions)
1975	12,114	9,378
1977	10,017	8,035
1978	10,296	8,387
1979	11,487	9,229
1980	9,955	8,197
1981	9,244	7,788

BUS SERVICE

The JNR total bus traffic in 1981 amounted to 2,486 million passenger-km, declining slightly by 0.6% from the previous year. This total includes an increase of 7.1% on expressway services, which gained from traffic to the Kobe Portopia exposition.

Bus service re-routing and rescheduling, including the closure of 12 routes (145 km) with low traffic density, permitted a reduction of 1.23 million vehicle-km from the previous year. Extra trips increased by 0.77 million vehicle-km, so that the net reduction was 0.46 million vehicle-km.

Bus Service Performance

Year							
1976	30.7	247 682	2 737	438	176	2 844	2 890
1977	30.4	227 896	2 568	391	372	3 337	2 786
1978	38.5	217 138	2 311	346	416	3 112	2 627
1979	39.0	217 035	2 089	383	488	2 941	2 562
1980	40.9	207 375	2 042	334	526	2 900	2 501
1981	42.5	202 246	2 134	340	522	3 016	2 486

FERRY SERVICE

Of the four JNR ferry routes, the Seikan (Aomori-Hakodate) and the Uko (Uno-Takamatsu) routes are the important ones linking trunk rail lines. These two routes carry freight cars as well as passengers. The Miyajima route also continues in service but the Nakata-Horie route was closed in early 1982.

Passengers carried on all four routes numbered 9,850 thousand, a decrease of 3% from the year before. The number of passengers on the Seikan decreased by 9%, and the Uko 6%.

Tons of freight carried on the Seikan and Uko routes decreased by 6% and 10%, respectively, over the previous year.

Ferry Service Performance

Year						
1976	43.9	2 782	15 245	8 895	34	75 504
1977	46.1	2 648	10 958	7 261	32	76 671
1978	46.8	2 564	10 617	7 370	30	76 [illegible]
1979	48.9	2 571	10 169	6 863	29	77 074
1980	48.4	2 471	10 148	6 887	29	77 826
1981	48.2	2 334	9 950	6 411	29	77 884

SUBSIDIARY ENTERPRISES

Revenue from JNR subsidiary enterprises maintained the annual growth rate of over 10 per cent that has been typical since 1976. Successful efforts to develop new services and some increases in rentals and other charges have made this growth possible despite the current sluggish economy and intensive competition.

Total revenue from these enterprises amounted to 63,500 million yen in 1981; the rate of increase, 12 per cent, was the largest since 1977. Rentals and commissions on services for passengers accounted for about 50 per cent of total revenue, and part of the increase in this category came from a 20 per cent growth in income from station buildings and station department stores. This growth was primarily the result of the construction and opening of 10 new station buildings.

By the end of 1981, JNR had invested a total sum of 26,100 million yen in 103 subsidiary enterprises. Of these 103, 81 were already in business and 62 of them showed profits in 1981.

Effective October 26, 1982, JNR was authorized to invest in enterprises that will handle transactions involving housing and office buildings on JNR property, in addition to the kinds of enterprises previously authorized such as port and harbor railways, freight terminals, passenger terminal facilities such as station buildings and hotels, advertising companies and ticket sales agencies.

Revenue from Subsidiary Enterprises

(thousand millions of yen)

Year	Total revenue from subsidiary enterprises	Index
1975	32.8	100
1977	43.0	131
1978	47.0	143
1979	51.1	156
1980	56.7	173
1981	63.5	193

(millions of yen)

	1980	1981	Ratio %
Rentals and commissions on services for passengers	28,081	31,764	113
Charges for advertising	14,122	15,848	112
Rental of land	9,907	10,835	109
Rental of parking areas	3,698	4,045	109
Rentals and commissions on services for freight customers	560	585	104
Dividends	176	248	141
Other revenue	128	126	98
Total	56,671	63,451	112

ROLLING STOCK AND TRAIN OPERATION

1. Number of Locomotives and Cars

More electric railcars have enabled JNR to increase train speed and improve its service

Locomotives and Cars

Year	Passenger cars	Freight cars	Electric railcars	Diesel railcars	Steam locos	Electric locos	Diesel locos
1975	6,725	120,597	16,502	5,326	15	2,051	2,204
1977	6,751	109,890	16,843	5,310	15	2,049	2,207
1978	6,567	101,042	17,247	5,233	5	1,978	2,160
1979	6,532	99,846	17,462	5,225	5	1,936	2,125
1980	6,176	99,562	17,696	5,038	5	1,856	2,109
1981	6,070	98,001	18,144	4,948	5	1,760	2,075

Note: Privately-owned cars are not included.

(1) Number of Electric Railcars

There has been a remarkable increase in electric railcars in recent years, as is seen in the following table

Electric Railcars

Year	For Shinkansen trains	For limited express trains	For ordinary express and suburban trains	For commuter trains	For other trains
1975	2,245	2,240	6,462	5,298	267
1977	2,354	2,297	6,599	5,325	268
1978	2,358	2,602	6,724	5,293	270
1979	2,372	2,635	6,935	5,276	290
1980	2,415	2,735	6,890	5,383	273
1981	2,646	2,899	7,213	5,214	172

(2) Number and Kinds of Freight Cars

Box cars	60,134
Refrigerator cars	1,614
Ventilated cars	74
Tank cars	16
Gondola cars	19,035
Flat cars	1,619
Container cars	6,626
Hopper cars	4,942
Others	3,941
Total	98,001

2. Electrification and Dieselization

As of March 1982, 39.9% or 8,435 km of the total route length was electrified. The JNR Motive Power Modernization Program was completed with the last steam locomotive withdrawn from service in March 1976. To meet popular demand, however, two steam locomotives, one each from the C57 and C58 classes, were restored to seasonal passenger service in August 1979 on the Yamaguchi Line.

Year	Route length AC/DC electrified (km)	Percentage of total route length
1975	7,628 (3,036)	35.9
1977	7,813 (3,210)	36.7
1978	8,032 (3,214)	37.7
1979	8,279 (3,335)	38.8
1980	8,414 (3,470)	39.5
1981	8,435 (3,470)	39.4

Notes 1. The figures in parentheses indicate the route length AC electrified
2. Route length electrified does not include the Shinkansen lines.

Train-kilometers by Type of Traction

(Daily average in thousands) (As of April 1982)

Passenger trains	Electric loco	Electric railcar	Diesel loco and railcar
	118.3 (8.4%)	887.0 (63.0%)	402.5 (28.6%)

Freight trains	Electric loco	Diesel loco
	311.0 (76.5%)	95.6 (23.5%)

3. Train Speeds

Scheduled speeds for various kinds of trains are shown below

(As of November 1982)

Kinds of trains		Scheduled speeds (km/h)
Passenger trains		
Locomotive-hauled trains	Limited express	65.5
	Ordinary express	52.8
	Local	35.6
Electric multiple unit trains	Shinkansen	
	Hikari	150.4
	Kodama	123.2
	Limited express	69.3
	Ordinary express	58.7
	Local	44.0
Diesel multiple unit trains	Limited express	61.3
	Ordinary express	51.6
	Local	35.1
Freight trains		
Limited express		60.3
Ordinary express		41.2
Others		25.5

Note: Scheduled speed = $\frac{\text{Distance between origin and destination stations}}{\text{Total time required including stopping time}}$

Speeds of Typical Fast Trains

(As of November 1982)

	Shinkansen train	Electric multiple unit train	Diesel multiple unit train	High speed freight train
Operating section	Tokyo–Hakata	Maibara–Kanazawa	Hakodate–Aboshiri	Tokyo–Osaka
Distance (km)	1,069	177	861	561
Scheduled speed (km/h)	180	85	84	70
Maximum speed (km/h)	210	120	100	95

4. Double-tracking

JNR has been placing high priority on double-tracking of its important trunk lines and, as of March 1982, double- and multi-tracked sections accounted for 28% or 5,654 km of its total route length.

Year	Double- and multi-tracked sections	
	Kilometers	Percentage
1975	5,424	26
1977	5,479	26
1978	5,530	26
1979	5,604	26
1980	5,641	27
1981	5,654	26

Note: Excludes the Shinkansen lines.

5. Number of Trains and Train-km per Day

(As of April 1982)

		Number of trains	Train-km (thousands)
Conventional Lines	Passenger trains	20,703	1,218
	Limited express	850	208
	Ordinary express	817	162
	Local	16,886	815
	Deadhead	2,350	33
	Express & baggage trains	143	41
	Mixed trains	31	2
	Freight trains	3,721	366
	Limited express	80	66
	Ordinary express	65	33
	Local	3,576	268
	Other trains*	2,349	5
	Sub-total	26,947	1,632
Shinkansen	Hikari	138	99
	Kodama	117	47
	Deadhead	277	6
	Sub-total	532	152
	Total	27,479	1,784

* Includes service trains & light engines.

MAINTENANCE AND SAFETY

1. Rolling Stock

Major repairs of rolling stock are done at 20 workshops in key locations throughout the country, and minor routine repairs and inspections are made at various depots. The repair and inspection work is now simplified through mechanization and automation and the intervals between inspections have been lengthened.

KICS (Kosaku Information Control System), which uses computers for modern management and operations at workshops, is proving quite effective in raising efficiency.

2. Track

Labor saving and mechanization of inspection are emphasized in the modernization of track maintenance work. Maintenance-free slab track, heavier rails and PC sleepers as well as machinery are used to reduce maintenance labor. High-speed track measuring cars are operated on the Shinkansen once every seven days, and on the conventional lines two to six times a year depending upon the need.

3. Structures

Maintenance standards have been established for bridges and tunnels, and repair and replacement work is carried out as necessary to keep these structures in good condition.

4. ATS

All JNR trains and lines have been equipped with an Automatic Train Stop system since 1966, and this has eliminated accidents from violation of signals.

5. ATC

Automatic Train Control systems are in use on the Shinkansen and several Tokyo subway lines. The entire Yamanote line in Tokyo was put under ATC in December 1981 for safer and more efficient commuter service, and wider use of ATC is planned.

6. CTC

In 1981, Centralized Traffic Control was installed on another 529 km, bringing the lines under CTC up to 6,144 km, or 29% of the total route length.

Year	Lines under CTC (km)	Percentage of total route length
1975	3,897	18
1977	4,878	23
1978	5,238	25
1979	5,463	26
1980	5,615	26
1981	6,144	29

Note: Excludes the Shinkansen lines.

7. Automatic Signals

Automatic signals were installed on 383 km of lines in 1981, raising the percentage of lines with such signals to 53% of the total route length.

Year	Single track (km)	Double track (km)	Total (km)	Percentage of total route length
1975	4,585	5,472	10,057	47
1977	5,105	5,527	10,632	50
1978	5,273	5,572	10,845	51
1979	5,391	5,598	10,989	52
1980	5,421	5,638	11,059	52
1981	5,758	5,664	11,422	53

Note: Excludes the Shinkansen lines

8. Level Crossings

Work continued on measures to reduce accidents at level crossings. Some level crossings were eliminated by relocating of railway track to elevated viaducts and construction of overpasses and underpasses; automatic barriers or warning signals were installed at others; and some crossings were closed.

Description	1975	1981
With barriers (manually, automatically or semi-automatically operated)	13,466	18,277
With warning signal device	5,132	3,473
Unprotected	12,566	7,935
Total	31,164	29,685

Note: Distance between level crossings averages 714 meters.

9. Train Operation Accidents

Accidents at level crossings are JNR's most serious safety problem. In spite of the increasing number of motor vehicles, however, these accidents are on the decrease.

Year	Train accidents	Level crossing accidents	Other accidents
1975	59 (0.09)	1,288 (2.05)	4
1977	41 (0.06)	1,077 (1.69)	0
1978	51 (0.08)	945 (1.39)	1
1979	61 (0.09)	839 (1.35)	0
1980	51 (0.08)	846 (1.40)	0
1981	33 (0.05)	771 (1.30)	2

Notes 1. The figures in parentheses indicate the number of accidents per million train-km
2. One accident giving rise to another is counted as two accidents.

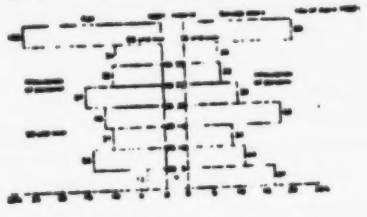
PERSONNEL

1. Number and Productivity of Employees

JNR continued to implement its policy of saving labor through modernization of motive power, improvement of working methods and mechanization of facilities.

Year	Number of employees	Pass.-ton-km per employee (thousands)	Index	Monthly average basic pay including family and area allowances (thousands of yen)	Index
1975	430,051	619	100	107	100
1977	428,928	569	91	157	147
1978	426,697	562	91	190	176
1979	420,815	572	92	197	184
1980	413,594	557	90	205	192
1981	401,362	561	91	215	201

2. Personnel Structures by Age and Service Year Groups



3. Employees by Organization

(As of April 1982)

	Number of employees
Railway Operating Divisions	20,767
Training Schools	1,416
Workshops	24,495
Hospitals and Clinics	3,385
Stations	110,418
Conductors' Depots	27,231
Engine Depots	47,947
Electric Railcar Depots	13,464
Car Operating & Repair Depots	23,275
Passenger & Freight Car Depots	12,570
Maintenance of Way Depots	40,067
Electric Power Depots	8,510
Signal & Telecommunication Maintenance Depots	10,010
Others*	57,817
Total	401,362

* Includes the Head Office, its auxiliary organizations, and the Shinkansen Administration.

REVENUES AND EXPENSES

1. General Account

The General Account shows operation revenues of 3,173,000 million yen and operating expenses of 4,325,400 million yen, resulting in an operating loss of 1,152,400 million yen. Adding the non-operating revenues to this amount and deducting the non-operating expenses yields a net loss of 1,085,900 million yen. The breakdown of this net loss into the specific retirement allowance loss of 263,800 million yen and the general net loss of 822,100 million yen shows that the general net loss decreased by 7,900 million yen (1%) from the previous year.

(1) Operating Revenues

Operating revenues amounted to 3,173,000 million yen, which was an increase of 209,300 million yen, or 7%, over the previous year. Three major factors led to this improvement: a system-wide increase in passenger fares and charges, aggressive promotion of rail travel, and increases in subsidies. Out of the operating revenues, passenger revenue accounted for 2,403,500 million yen, an increase of 181,000 million yen (7%), while freight revenue was 311,400 million yen, a decrease of 18,200 million yen (6%). Miscellaneous revenue amounted to 115,400 million yen, up 12,800 million yen (13%); of this, revenue from subsidiary enterprises totaled 63,500 million yen, up 6,800 million yen (12%). Subsidies for specific retirement allowances and construction expenses were increased, and total subsidies received amounted to 342,800 million yen, an increase of 53,700 million yen (19%).

(2) Operating Expenses

Operating expenses totaled 4,325,400 million yen, showing an increase of 361,200 million yen, or 9%, over the previous year. This was despite the efforts exerted to reduce operating expenditures through greater efficiency. Factors causing the increase included an increased number of personnel retiring during the year, increased provision for pensions through the mutual aid association, higher wage payments in accordance with arbitration, larger interest payments on long-term debts, and greater bond handling expense. Of the operating expenses, personnel expense was 2,007,200 million yen, up 148,500 million yen (8%); material expense, including taxes & other public payments, 1,296,500 million yen, up 65,200 million yen (5%); and capital expense (interest, bond handling expense and depreciation) 1,021,800 million yen, up 147,600 million yen (17%). Personnel, material and capital expenses accounted for 46%, 30% and 24%, respectively, of the operating expenses.

Revenues & Expenses of General Account

(Thousand millions of yen)

Year / Classification	1976	1977	1978	1979	1980	1981
Operating revenues	1,859.1	2,369.0	2,670.2	2,963.7	2,963.7	3,173.0
Passenger	1,515.1	1,889.0	1,940.9	2,156.0	2,242.4	2,403.5
Freight	277.0	297.0	288.5	263.0	329.6	311.4
Miscellaneous	71.4	70.7	88.8	88.8	102.5	115.4
Subsidies for specific-reason allowances	114.8	108.8	291.9	356.4	289.1	342.8
Operating expenses	2,915.8	3,214.7	3,471.4	3,744.8	3,964.3	4,325.4
Personnel	1,398.8	1,530.2	1,666.7	1,720.3	1,858.7	2,007.2
Material	875.6	939.8	989.8	1,089.7	1,201.4	1,263.9
Taxes & other public payments	21.8	23.7	26.5	27.3	29.8	32.6
Interest & bond handling expenses	318.8	401.8	427.7	552.5	576.4	693.8
Depreciation	388.3	319.8	342.8	373.8	397.8	418.8
Operating profit or loss	-1,027.8	-845.7	-801.2	-847.5	-1,000.6	-1,152.4
Non-operating revenues	12.1	16.8	16.8	23.8	26.9	73.1
Non-operating expenses	3.7	3.8	4.2	3.2	42.7	6.6
Net profit or loss	-814.1	-833.8	-788.7	-821.8	-1,000.4	-1,085.9
General net loss	-	-	-550.9	-720.2	-829.8	-822.1
Specific retirement allowances net loss	-	-	-76.8	-93.6	-170.4	-263.8

Note: In 1976 a Separate Account for Specified Construction Loans was established. This is separate from the General Account.

Balance Sheet of General Account

(Thousand millions of yen)

Year / Classification	1976	1977	1978	1979	1980	1981
Assets	7,338.5	8,897.4	10,691.4	12,538.9	11,188.3	13,196.7
Fixed assets	5,715.8	6,788.8	7,148.9	8,695.7	8,875.4	9,744.4
Investments	101.4	103.2	107.1	111.2	114.8	119.8
Working assets	48.9	51.7	47.3	53.4	53.1	54.4
Current assets	389.6	452.6	488.7	653.4	683.2	684.3
Deferred assets and others	168.8	162.2	183.5	188.5	184.8	207.4
Deficit carried over	974.2	1,288.2	2,564.8	3,516.7	1,178.8	2,384.7
Liabilities & Equity	7,338.5	8,897.4	10,691.4	12,538.9	11,188.3	13,196.7
Long-term liabilities	5,458.2	6,886.8	8,451.9	10,148.2	9,877.8	10,879.4
Short-term liabilities	456.7	517.1	682.8	686.4	911.1	913.3
Other liabilities	187.8	142.8	256.8	413.5	534.7	726.8
Capital	456.8	456.8	456.8	456.8	456.8	456.8
Capital reserves	868.8	886.7	886.7	886.7	886.8	891.5

Note: In 1976 a Separate Account for Specified Construction Loans was established. This is separate from the General Account.

2. Separate Account

A Separate Account was established in 1976 for specified government loans excluded from the General Account. This account continues to be excluded from the General Account as the Separate Account for Specified Government Loans, in accordance with the Japanese National Railways Management Rehabilitation Promotion Special Act of 1980.

Balance Sheet of the Separate Account for Specified Government Loans

(thousand millions of yen)

	1976	1977	1978	1979	1980	1981
Assets						
Specified deficit carried forward	2,540.4	2,540.4	2,540.4	2,540.1	5,322.1	5,322.1
Liabilities						
Long-term liabilities	2,540.4	2,540.4	2,540.4	2,540.1	5,322.1	5,322.1
Specified long-term loans	2,481.3	2,417.9	2,349.7	2,278.5	5,059.9	5,059.9
Loans for financial rehabilitation	59.1	122.5	190.7	263.6	262.2	262.2

Receipts and Disbursements of the Separate Account for Specified Government Loans

(thousand millions of yen)

	1976	1977	1978	1979	1980	1981
Receipts	185.0	180.6	175.9	171.2	386.4	345.7
Interest subsidy on loans for financial rehabilitation	185.0	180.6	175.9	170.9	345.7	345.7
Received from the General Account	–	–	–	0.3	40.7	–
Disbursements						
Interest on specified long-term loans	185.0	180.6	175.9	170.9	346.4	345.7
Appropriation for specified deficit carried forward	–	–	–	0.3	40.0	–

3. Separate Accounting by Groups of Lines

Under separate accounting by groups of lines, trunk lines registered a net loss of 700,500 million yen and local lines a loss of 347,300 million yen. Buses showed a 38,100 million yen loss.

The local lines as a group accounted for 10,800 million passenger-ton-km, only 5% of the total traffic. The loss sustained, however, represented 32% of the total net loss.

Profit and Loss Account of Trunk Lines and Local Lines for Fiscal 1981

Item \ Classification		Trunk lines (including commuter lines in metropolitan areas)	Local lines	Buses	Total
Route-km		12,844.7 (55.4%)	10,174.3 (44.6%)	14,052.6	36,871.6
Traffic volume	Passenger-km (thousand millions)	183.0 (85.1%)	9.5 (4.9%)	2.5	195.0
	Ton-km (thousand millions)	32.7 (96.3%)	1.3 (3.7%)	0	34.0
Revenues (thousand millions of yen)					
	Passenger	2,288.8	94.7	38.7	2,403.4
	Freight	293.1	17.5	0.8	311.4
	Miscellaneous	110.3	4.5	0.6	115.4
	Subsidies	212.5	128.2	2.1	342.8
	Total	2,895.7 (82.7%)	245.1 (7.8%)	42.2	3,173.0
Expenses (thousand millions of yen)					
	Operating	2,735.1	497.4	71.2	3,303.7
	Capital	912.0	100.3	9.4	1,021.7
	Total	3,647.1 (85.9%)	597.7 (14.1%)	80.6	4,325.4
Operating profit or loss (thousand millions of yen)		–751.4	–352.6	–38.4	–1,152.4
Non-operating profit or loss (thousand millions of yen)		50.9	5.3	0.3	56.5
Net profit or loss (thousand millions of yen)		–700.5 (64.5%)	–347.3 (32%)	–38.1 (3.5%)	–1,085.9 (100%)
	General net loss	–486.4	–303.6	–32.1	–822.1
	Specific retirement allowance net loss	–214.1	–43.7	–6.0	–263.8

4. Management Improvement Plan

Following the passage of the Law Providing Special Measures for Promotion of JNR Rehabilitation on December 27, 1980, JNR submitted its Management Improvement Plan, which was approved by the Minister of Transport on May 21, 1981. This thorough, comprehensive plan should restore JNR financial stability through the changes and improvements outlined below.

(1) Priorities, Rationalization and Efficiency

The transportation services to be emphasized are those that make the best use of the inherent characteristics of railways - intercity passenger transport, commuter traffic in metropolitan areas, large-volume freight movement, and freight transportation over fixed routes on regular schedules.

Service patterns are to be changed where traffic volume on local railway lines is too light for efficient railway operation.

Overall work efficiency, as measured by transportation service performed per employee, is to be raised, goals are a 25% increase in efficiency and a reduction to a staff of 350,000 by 1985.

(2) Revenues

JNR's spirit of enterprise and competition will be strengthened, to increase traffic and revenues where the JNR share of traffic has fallen behind other transport modes.

Tariff revision will be made in appropriate ways and at proper times, while maintaining a fair and just tariff structure.

Efforts will be made to increase revenues from JNR's subsidiary enterprises, which should contribute about ¥500,000 million from the start of the plan through 1985; some properties will be disposed of, and this would yield about the same amount

(3) Investment

Because high capital costs have adversely affected recent financial results, investment in facilities is to be kept to a minimum; the investment scale during the plan period is to remain at the present level.

(4) Industrial Relations

Every effort will be made to improve labor-management relations and to maintain working standards, as these are essential to accomplish the objectives of the plan.

(5) Targets

The financial targets of this plan are to increase the general operating profit as much as possible and to reach the break-even point on trunk lines by 1985, in order to establish a sound financial basis for management.

From 1986, efforts will be made to bring the entire system to the break-even point as quickly as possible.

Revenues and Expenses

(Thousand millions of yen)

Classification	Fiscal year	1980	1985
Trunk lines	Operating revenues	2 607.7	3 840.0
	Operating expenses	2 784.4	3 360.0
	Operating profit or loss	-176.7	480.0
	Non-operating profit or loss	-271.6	-480.0
	Net profit or loss	-448.3	10.0
Local lines and buses	Operating revenues	125.0	180.0
	Operating expenses	475.2	600.0
	Operating profit or loss	-350.3	-270.0
	Non-operating profit or loss	83.8	-10.0
	Net profit or loss	-266.5	-230.0
Specific personnel expenses	Specific retirement allowances	-158.4	-260.0
	Specific pensions	-154.4	-310.0
	Non-operating loss (carryover)	-11.3	-200.0
	Total	-324.1	-770.0
Total revenues and expenses	Operating revenues	2 732.7	4 020.0
	Operating expenses	3 572.5	4 330.0
	Operating profit or loss	-839.8	-300.0
	Non-operating profit or loss	-190.1	-680.0
	Net profit or loss	-1 038.9	990.0
General operating profit or loss (trunk and local lines and buses)		-527.0	370.0

Notes 1 Capital expenses of 400 000 million yen for the Tohoku and Joetsu Shinkansen lines are not included.

2 Figures for fiscal 1980 are based on the supplementary budget.

Traffic Volume

(Thousand millions)

Item	Fiscal year	1980	1981	1982	1983	1984	1985
Passenger-km	Train	193.7	193.8	195.8	198.6	201.7	204.7
	Ferry	0.4	0.4	0.4	0.4	0.4	0.4
	Bus	2.5	2.5	2.5	2.5	2.5	2.5
	Total	196.6	196.7	198.7	201.5	204.1	207.1
Ton-km	Train	39.4	41.9	41.6	41.7	41.8	41.9
	Ferry	0.7	0.7	0.7	0.7	0.7	0.7
	Total	40.1	42.7	42.3	42.4	42.5	42.6
Passen-km	Train	233.1	235.3	238.4	240.3	242.8	245.1
	Ferry	1.1	1.1	1.1	1.1	1.1	1.1
	Bus	2.5	2.5	2.5	2.5	2.5	2.5
	Total	236.7	238.9	242.0	243.9	246.4	248.7

Note Figures for 1980 are based on the budget.

Transport Capacity

(Thousand)

Item			Fiscal year 1980	1985
Passenger train km/day	Shinkansen		178	230
	Conventional lines	Limited and ordinary expresses	414	310
		Other trains	845	840
	Total		1 437	1 380
Freight train km/day			670	600
Baggage car km/day			407	360
Ferry km			2 463	2 290
Bus km			110 000	110 000

Employees and Productivity

Item	Fiscal year 1979	1980	1981	1982	1983	1984	1985	Total change
Employees at start of year	430 000	419 500	408 500	395 500	382 200	365 700	350 000	-
Increase during year	6 000	8 400	7 000	2 300	2 800	1 300	-	29 000
Turnover	-8 500	-10 400	-14 000	-15 600	-19 300	-17 000	-	-94 000
Net change	-6 500	-11 000	-13 000	-15 300	-16 500	-15 700	-	-74 000
Traffic volume per employee (thousand person-km per man-km)	-	464	485	510	540	570	710	-
General personnel expenses as percentage of operating revenues	-	74	69	64	60	55	51	
Operating revenues per employee (thousand yen)	-	6 514					11 500	

Personnel Reduction

Measure	Staff reduction
Shorter hours of work (monthly)	
Heavy efficient use of work power (main items: labor-management programs)	19 500
Improvements to improve personnel productivity	
Shifting work and facilities to areas and work generally in declining and long-term for steps of work improvements)	18 600
Shorter hours through improvements	
ME/IC applications (signs, and other facilities)	8 900
Redeployment in regular and yard personnel	
Steps of efficient use of personnel (main components/systems)	
Surplus personnel (consolidation and outsourcing/work-sharing and counseling)	11 200
Transfer of personnel from lines to companies	
Use of surplus work forces created by railway employees in unrelated jobs in companies and new businesses	31 100
Reorganization and changes of local lines	
Use of these measures to improve efficiency of original local railway lines and reorganization of liability-paid local lines by bus service	15 000
Total	44 300

Facilities and Rolling Stock

	1980	1985
Route length, km	21,372	18,420
Passenger stations		
Manned	2,892	1,600
Unmanned	2,293	2,870
Total	5,185	4,470
Freight stations	1,358	800
Yards	193	100
Rolling stock:		
Locomotives	4,061	3,600
Passenger cars	29,219	28,000
Freight cars	99,846	92,000
Buses	2,547	2,400
Ferries, total gross tonnage	72,000	65,000

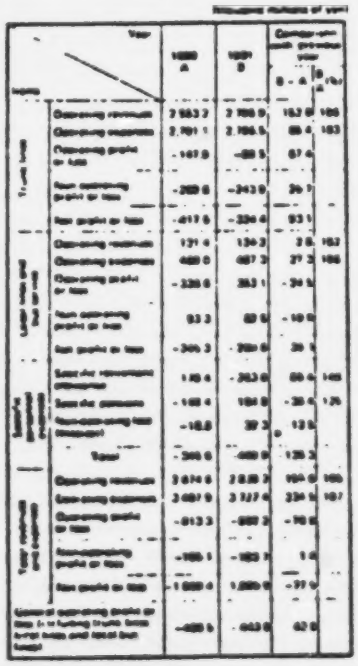
Note All entries are for the beginning of both fiscal years except route lengths, which are as of the start of fiscal 1980 and the end of fiscal 1985

5. Major Results Under the Management Improvement Plan

○ Revenues and Expenses

The revenues and expenses for 1981, the first year of the Management Improvement Plan, are as shown in the following table. Although trunk line freight revenue decreased from the previous year, revenue from passenger traffic and subsidiary enterprises increased. Efforts were made to reduce personnel and operating costs and to increase non-operating revenues. As a result, the trunk line loss was reduced by 93,100 million yen from the previous year. This is a significant step toward bringing revenues and expenses on trunk lines in balance by the target year of 1985.

Revenues and Expenses



○ Traffic Volume

Passenger traffic volume (excluding ferry and bus) registered 192,100 million passenger-km, a decrease of 0.8% from the previous year. This is 0.9% lower than the goal set under the Management Improvement Plan. Freight traffic volume (excluding ferry and bus) sharply declined for the second consecutive year; the figure of 33,400 million ton-km was 9.6% below the previous year and 20% below the goal in the Management Improvement Plan.

Passenger Traffic Volume

(thousand passenger-km)

Item \ Year	1980 A	1981 Goal B	1981 Actual C	Comparison (%) C/A	Comparison (%) C/B
Passenger traffic volume	193.1	193.8	192.1	99.5	99.1

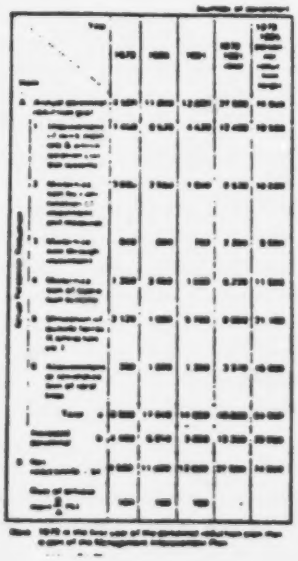
Freight Traffic Volume

Item \ Year	1980 A	1981 Goal B	1981 Actual C	Comparison (%) C/A	Comparison (%) C/B
Freight traffic volume	37.0	41.5	33.4	90.4	80.5

○ Personnel Reduction and Productivity Index

Measures for modernization and efficiency have included improvements in work methods, administration and operation systems, as well as increased utilization of outside contractors. The reduction of 12,000 personnel scheduled by the Management Improvement Plan was achieved. The productivity index for 1981 was 4% lower than the goal for this index.

Personnel Reduction



Productivity Index (Traffic volume per employee)

(thousand passenger-ton-km)

Item \ Year	1980	1981
Goal A	564	585
Actual B	557	561
Comparison $\frac{B}{A}$ (%)	99	96

SHINKANSEN

1. Tokaido-Sanyo Shinkansen

The Tokaido Shinkansen began service between Tokyo and Shin Osaka on October 1, 1964. Its westward extension, the Sanyo Shinkansen, was opened to Okayama on March 15, 1972 and to Hakata on March 10, 1975. The total length from Tokyo to Hakata is 1,069 km. In their first 17 years, Shinkansen trains have carried over 1,700 million passengers without a single casualty.

Two types of trains are operated. Hikari trains stop only at principal stations, connect Tokyo and Shin Osaka in 3 hours 10 minutes, and, on the fastest runs, take only 6 hours 40 minutes for the trip between Tokyo and Hakata. Kodama trains serve all intermediate stations, with typical travel times of 4 hours 14 minutes from Tokyo to Shin Osaka and 4 hours 24 minutes from Shin Osaka to Hakata. In the peak period, as many as 255 trains are operated a day, 138 Hikari and 117 Kodama.

Passengers carried in 1981 totaled 125.6 million (a daily average of 344,000); passenger-km 41,717 million; and the distance traveled per passenger 332 km.

Revenue and Expense

(thousand millions of yen)

Year	1975	1977	1978	1979	1980	1981
Revenue	477.9	615.9	653.6	698.9	729.8	768.9
Expense	256.9	370.5	374.3	389.1	439.5	446.6
Operating ratio (%)	62	60	57	57	59	57

Traffic

Year	1975	1977	1978	1979	1980	1981
Passengers carried (thousands)	167,318	136,788	123,889	122,767	125,638	125,619
Passenger kilometers (millions)	53,318	42,187	41,074	40,888	41,780	41,717
Average passengers carried per day (thousands)	430	347	339	338	344	344
Average distance traveled per passenger (km)	339	333	333	331	333	332

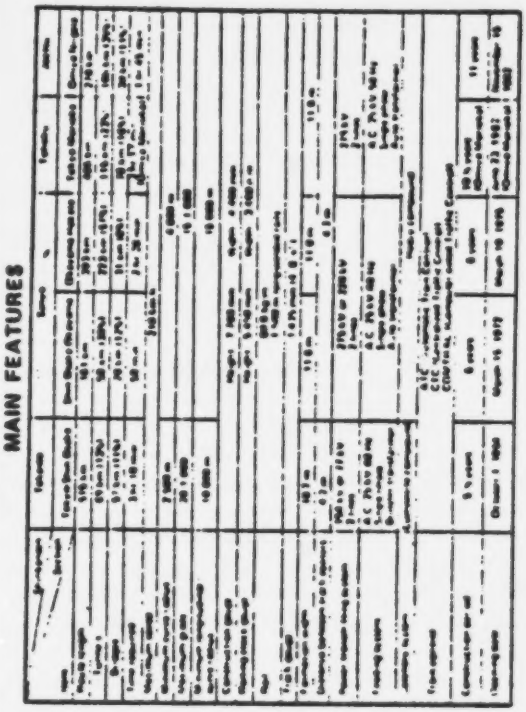
2. Tohoku Shinkansen

The Tohoku Shinkansen was opened between Omiya and Morioka, 466.2 km, on June 23, 1982. Two types of super express trains, similar to those on the Tokaido and Sanyo, are operated – 36 Yamabiko and 24 Asbe. Yamabiko trains stop only at important stations between Omiya and Sendai, then at all stops to Morioka, taking 3 hours 17 minutes; Asbe trains stop at all stations to Sendai, taking 2 hours 17 minutes.

3. Joetsu Shinkansen

The Joetsu Shinkansen began service on November 15 between Omiya and Niigata, 269.5 km. Asahi super express trains operate on 11 return trips, stopping only at major stations, and Toki super expresses on 10 return trips, stopping at each station. Running time for an Asahi train which stops only at Takasaki and Nagaoka is 1 hour and 45 minutes, and for a Toki train 2 hours and 10 minutes, between Omiya and Niigata.

MAIN FEATURES



NATIONWIDE SHINKANSEN NETWORK

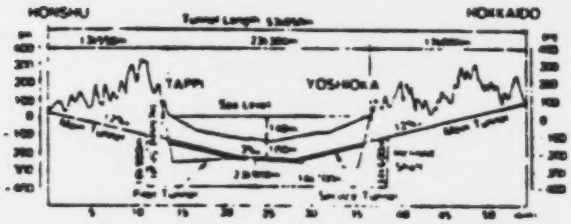
Construction plans for three Shinkansen lines were confirmed by the Law for Construction of Nationwide High-speed Railways, which was enacted in May 1970 to encourage the economic growth and well-balanced land development envisioned in the New Comprehensive National Development Plan of 1969 and the New Economic and Social Development Plan of 1970. Two of these lines opened in 1982; the Tohoku Shinkansen opened between Omiya and Morioka on June 23, and the Joetsu between Omiya and Niigata on November 15. Construction is in progress between Tokyo and Omiya. Some work has also been done on the third new line, the Narita Shinkansen from Tokyo to New Tokyo International Airport.

Five other Shinkansen lines are planned: Hokuriku (Tokyo-Osaka via Toyama), Tohoku (Morioka-Aomori), Kyushu (Hakata-Kagoshima), Nagasaki (Hakata-Nagasaki) and Hokkaido (Aomori-Sapporo). Their construction has been deferred for financial reasons; environmental surveys and other preparatory work are under way on the first three of the five, which are to be given priority. Twelve additional lines have been proposed. Progress continues on the undersea tunnel between Honshu and Hokkaido and suspension road-rail bridges between Honshu and Shikoku.

Seikan Undersea Tunnel between Honshu and Hokkaido

Length:	53.85 km (23.3 km undersea)
Max. depth:	240 m under sea level
Construction period:	About 13 yrs, completion set at 1984 at the earliest
Construction cost:	About 531,000 million yen

Profile of Main Tunnel



Suspension Road-Rail Bridges between Honshu and Shikoku

Bridges on the Kobe-Naruto Route ..... Expected cost 1,685,000 million yen

Bridges on the Kojima-Sakaide Route ..... Expected cost 1,110,000 million yen

For the construction of these bridges, the Honshu-Shikoku Bridge Authority was established in July 1970, and construction work on the Onaruto Bridge, one of the two main bridges on the Kobe-Naruto route, started in July 1976.

TECHNOLOGICAL DEVELOPMENT

In order to recover financial stability while continuing to fulfill its vital transportation missions, JNR must operate more efficiently and economically, reduce its work force, and provide needed services with high standards of safety. At the same time, JNR must develop new transport systems and minimize the impact of railway operations on the environment.

In view of the above, JNR is constantly in pursuit of technological progress. Projects carried forward in 1981 include the following:

1. Operational Improvements

(1) Speed Increase for Conventional Lines

Development work continued on new, faster limited express railcars. These cars will be designed to operate at a 130 km/h top speed and 120 km/h through turnouts for passing, without requiring major changes to ground facilities. Research areas receiving special attention included:

- Development of braking systems that will stop trains within 600 m.
- Production of experimental bogies designed for better riding quality and reduced likelihood of track damage.
- Studies of the characteristics of coupling mechanisms for twin-unit articulated vehicles.
- Tests of high-speed running through turnouts.

(2) Speed Increase for Shinkansen Lines

In parallel with research efforts for development of new rolling stock capable of operation at 260 km/h, which is the intended future Shinkansen speed, research continued on the possibility of a speed increase to 230 km per hour by modification of the present 200-series cars. Particular emphasis was given to:

- Tests of car running performance on track that is uneven or out of alignment.
- Studies of bolsterless bogies.
- Studies of powered banking devices for car bodies.
- Production of experimental lightweight cars with a cross-section shape designed for higher speeds.

(3) Energy Saving

Research was continued to develop new technologies for reducing power costs and energy consumption, such as economical driving method, efficiency improvements in direct jet type diesel engine and power regeneration equipment, vehicle weight reduction, and easier coupling and uncoupling.

Efforts for diversification of energy sources were continued. An example is the use of solar energy as an alternative to oil.

(4) Other Research

Studies were made on other topics, such as reduction of noise from Shinkansen operations and office automation through the use of microcomputers.

2. Safety, Security and Reliability

(1) Research was continued into problems of multiple-cause freight train derailments. Data were collected from running tests and equipment was developed for testing vehicle motion.

In parallel with these field tests, studies will be directed

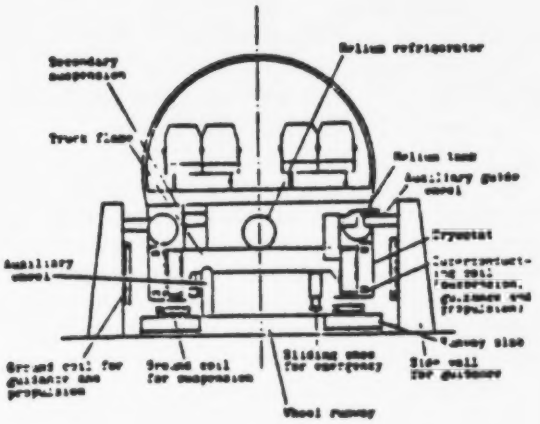
(2) Methods for preventing failures of overhead contact wires and pantographs were examined. Research included the development of contact wires and pantograph pans with good capabilities for resisting wear, detection devices to give early warnings of failures, and equipment and methods to diagnose problems and measure deterioration.

3. Maglev System

JNR continued to experiment with Maglev (magnetically levitated) vehicle technology on a 7-km test guideway near Miyazaki. Test vehicle ML-500 reached a record speed of 517 km/h in December 1979, bringing this series of tests with an inverted-T-shaped guideway to a successful conclusion. The guideway then was modified into a U-shaped configuration, and tests were run with a new vehicle, MLU-001, as a single car and as a two-car train. On September 2, 1982, coupled cars MLU 001-1 and 001-3 reached 262 km/h in levitated operation and for the first time was carrying three persons aboard. A third car has since been added, and tests will continue into 1983.

In parallel with these field tests, studies will be directed toward development of operational concepts for a Maglev system and toward technologies for vehicle control at turnouts, power supply, on-board power sources, and emergency braking. Research will also treat vehicle-guideway dynamics and precise measurement of guideway irregularities, reduction of reactive power, performance of associated equipment, and human body reactions to magnetic effects and to high-speed running.

Standard Cross Section of
Test Vehicle and Guideway



ENVIRONMENTAL PROTECTION

1. Shinkansen Train Noise and Vibration

JNR has been making efforts to reduce noise from Shinkansen trains in response to the Environment Agency notification issued in July 1975, "Environmental Quality Standards for Shinkansen Railway Noise," and other related directives.

Noise source countermeasures have included noise barrier walls along the line and noise dampers on steel girder bridges. These have already been installed as planned. Since 1976, measures have been taken to quiet the air-pressure sound made by trains going through tunnels.

JNR has also requested the cooperation of local governments in negotiations with the great number of residents whose homes have been affected by train noise, and has worked to soundproof or relocate the houses, and take other compensatory steps in these cases.

JNR has carried out house relocation work where train vibrations have been unusually heavy, and has developed and introduced new methods to protect houses from the impact of vibrations.

2. Other Problems

JNR has been working on equipment and procedures for disposal of waste from train toilets, prevention of air and water pollution, and reduction of TV and radio interference.

ENERGY EFFICIENCY BY TRANSPORT MODE

The energy efficiency of railways is relatively higher than other modes of transport. In 1981, trains accounted for 41% of the total domestic passenger-km, while using only 10% of the energy consumption for passenger transportation. Rail freight, 9% of the total domestic ton-km, accounted for only 2% of the total energy used for freight movement.

	Trains	Automobiles	Buses	Other modes	Total
Passenger-km (%)	41	39	10	10	100
Energy consumption (%)	10	69	4	17	100

	Trains	Trucks		Coastal ships	Total
		Private, owned	Common carrier		
Ton-km (%)	9	17	23	5	100
Energy consumption (%)	2	56	25	17	100

INTERNATIONAL COOPERATION

The railway engineering capabilities of JNR are highly valued overseas, especially since the opening of the Shinkansen, and requests for technical cooperation to JNR are ever increasing.

As a means of international cooperation, JNR sends its experts abroad and receives trainees from overseas when requested by a government or a public organization and when considered appropriate by JNR. JNR is doing this as part of national policy.

1. Dispatch of JNR Experts

Requests for cooperation have been coming mostly from the developing countries lately. However, JNR has been responding to technical cooperation to some advanced countries as well. They include assistance on technical projects of a comprehensive nature, such as modernization of a complete railway system, urban transport as part of city planning, and establishment of an integrated transportation system including railways, as well as on the survey and appraisal of the economic effects of such projects.

JNR complies with these requests and presently its experts are living as they are widely active abroad. It renders such cooperation through the Japan International Cooperation Agency (JICA) and Japan Railway Technical Service (JARTS), which has been strengthened to deal with expanding requests for railway technical cooperation.

In 1981, JNR continued to extend technical cooperation to many countries in the world, including the U.S.A., China, Zaire, Brazil, Mexico and Bolivia. JNR assigned 219 specialists and experts to overseas technical cooperation positions.

2. Trainees and Visitors from Abroad

Each year JNR receives railway trainees from various countries on request of their respective governments. In 1981, 78 trainees from 21 countries were enrolled through JICA, individually or in groups, to take various courses for two to four months.

Trainees are given a course of lectures by JNR experts. Their field studies include visits to the Railway Technical Research Institute, CTC centers, workshops, construction sites and other railway facilities.

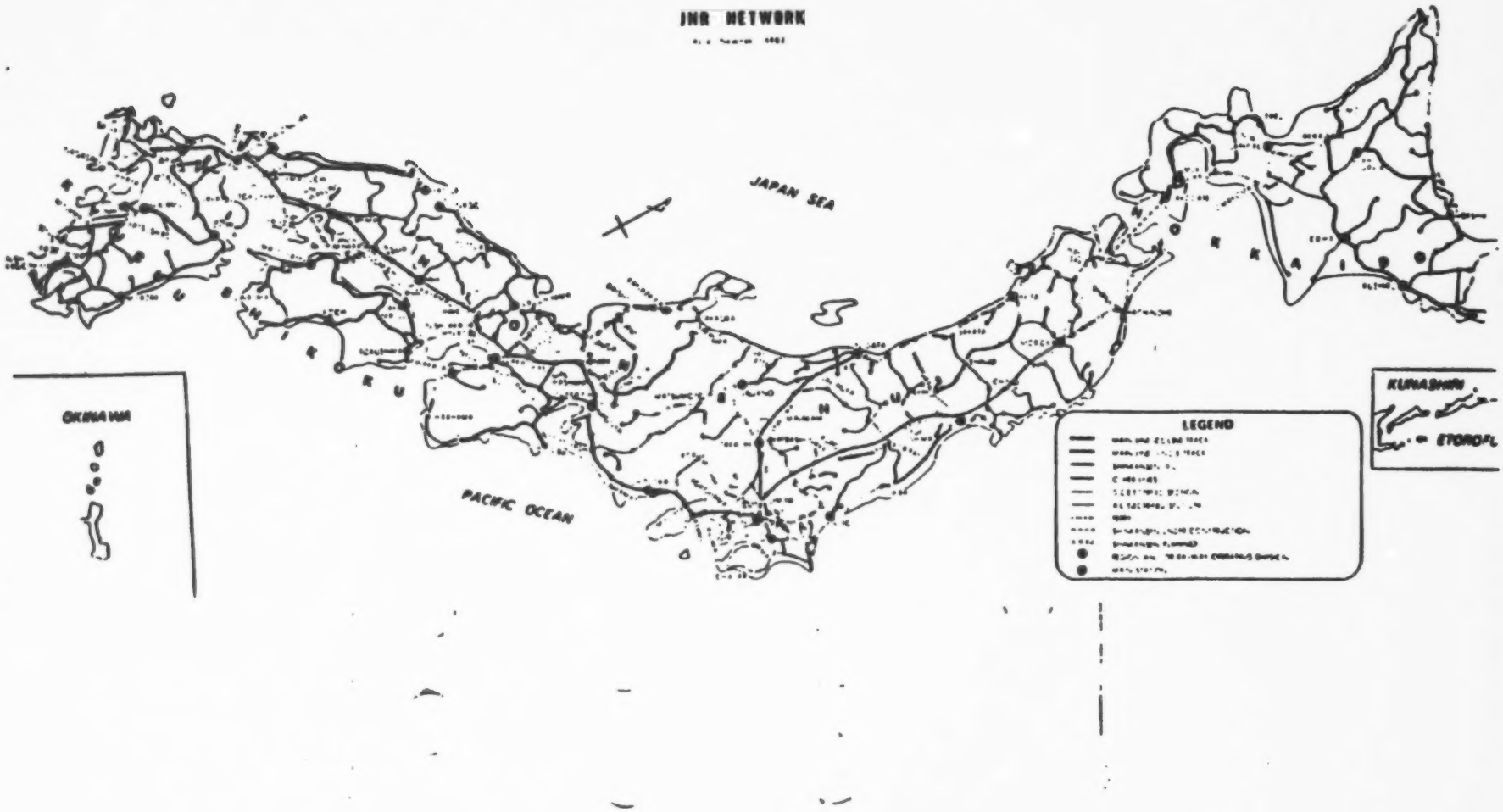
JNR also provides official visitors from abroad with assistance in field visits and discussions with JNR experts. In 1981 they numbered as many as 997 from 62 different countries.

3. Overseas Offices

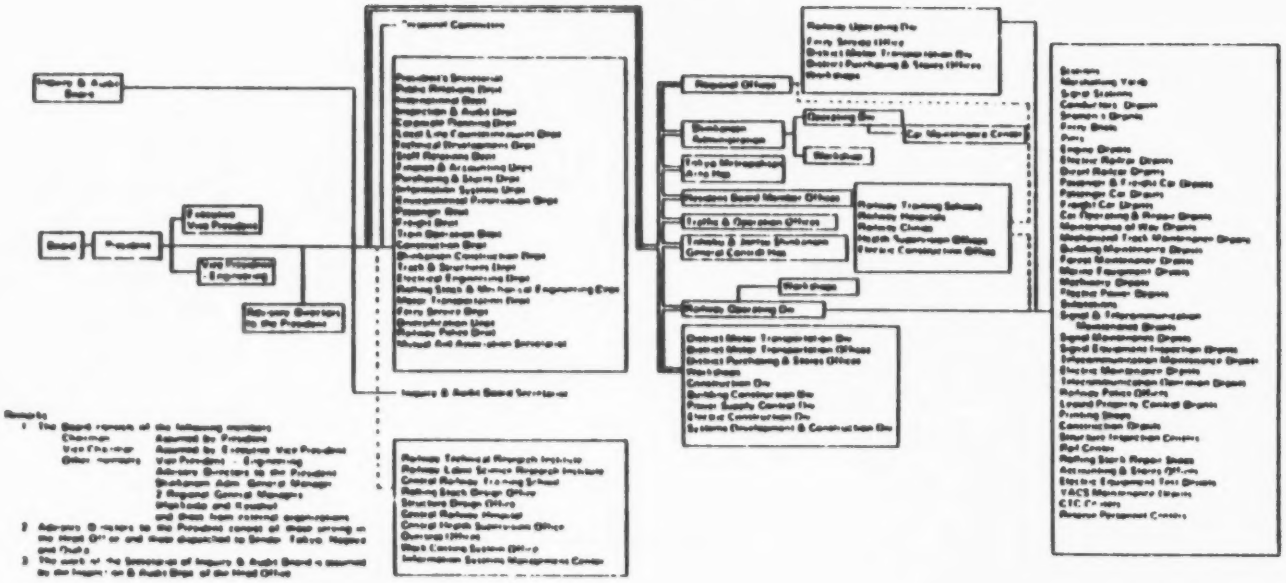
JNR has overseas offices in New York and Paris to study transportation conditions abroad, collect data and information on transportation, arrange JNR participation in international railway meetings, communicate and negotiate with international railway organizations and carry on public relations activities.

CHRONOLOGY

Oct.	14,	1872	First railway in Japan opened to traffic between Shimbashi (Tokyo) and Yokohama.
July	1,	1889	Tokaido Line completed, linking the six major cities of Tokyo, Yokohama, Nagoya, Kyoto, Osaka and Kobe.
Sept.	1,	1891	Tohoku Line (Ueno-Aomori) connecting northern and central Japan, constructed by Nippon Railway Company.
May	27,	1901	Sanyo Line (Kobe-Shimonoseki) opened to traffic, with ferry service between Shimonoseki and Moji, the entrance to Kyushu.
Mar.	31,	1906	Government purchased the major private railways.
Mar.	7,	1908	Ferry service commenced between Aomori and Hakodate.
Dec.	5,	1908	Railway Board set up under the Cabinet.
Dec.	20,	1914	Tokyu Station opened.
May	15,	1920	Ministry of Railways established.
Nov.	1,	1925	Loop operation of Yamanote Line electric railcar train started.
Dec.	1,	1934	Tanna Tunnel on the Tokaido Line completed after 16 years of work.
June	11,	1942	Kammon Undersea Tunnel (Shimonoseki-Moji) completed.
Nov.	1,	1943	Ministry of Transport and Telecommunication set up, absorbing Ministry of Railways.
May	18,	1945	Ministry of Transport and Telecommunication reorganized into Ministry of Transport.
June	1,	1949	Government Railways reorganized into a public corporation called the Japanese National Railways (JNR).
Nov.	19,	1956	Electrification of the Tokaido Line completed.
Apr.	20,	1959	Ground breaking ceremony for construction of the New Tokaido Line (Tokaido Shinkansen) held.
Nov.	5,	1959	Container freight train service commenced between Tokyo and Osaka.
July	31,	1961	Hokuriku Tunnel (13,870m), world's 5th longest, bored through.
Mar.	30,	1963	Record 256 km/h achieved by a prototype train on the test-run section of the Tokaido Shinkansen.
Oct.	1,	1964	Tokaido Shinkansen opened to traffic.
Oct.	5,	1964	JNR bus service opened on the Nagoya-Kobe Expressway.
Apr.	20,	1966	Automatic Train Stop (ATS) equipment applied to entire system.
Feb.	24,	1972	Record 286 km/h achieved by a new prototype Shinkansen train.
Mar.	15,	1972	Shinkansen extended to Okayama.
Sept.	19,	1972	Superconducting magnet levitated, linear induction motor propelled experimental vehicle (ML-100) successfully run.
July	10,	1973	Debut of pendulum electric multiple-unit limited express on the Chuo Line.
Mar.	15,	1974	Shin Kammon Undersea Tunnel on the Shinkansen bored through.
Sept.	3,	1974	Linear motor car shunting system introduced in Shiohama Marshalling Yard.
Mar.	10,	1975	Shinkansen extended to Hakata.
May	5,	1975	Record 1,032,136 passengers carried on the Shinkansen in a single day.
May	25,	1976	One billion passengers carried on the Shinkansen since its inception.
Sept.	21,	1977	Running tests of a superconducting magnet levitated, linear synchronous motor propelled experimental vehicle (ML-500) started at the Miyazaki Maglev Test Center.
Dec.	7,	1979	Record speed of 319 km/h achieved by a train of 961 type cars on the Shinkansen test track, Ohmiya.
Dec.	21,	1979	Record speed of 517 km/h reached by the Maglev vehicle on the Miyazaki test track.
Dec.	27,	1980	The Law Providing Special Measures for Promotion of JNR Rehabilitation enacted.
June	23,	1982	Tohoku Shinkansen opened to traffic.
Nov.	15,	1982	Joetsu Shinkansen opened to traffic.


JNR NETWORK
JAPAN SEA
PACIFIC OCEAN
OKINAWA
LEGEND
KUNASHIRI
ETOROFU

JNR ORGANIZATION CHART



APPENDIX 1.3

PRESENT SITUATION OF JAPANESE RAILWAYS

（日本の鉄道の現況）

1983

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（参考）

Organization of Ministry of Transport
（運輸省組織図）

1. Transition of the Traffic Volume by Various Modes of Transport (Statistical Data of District Land Transport Bureau)

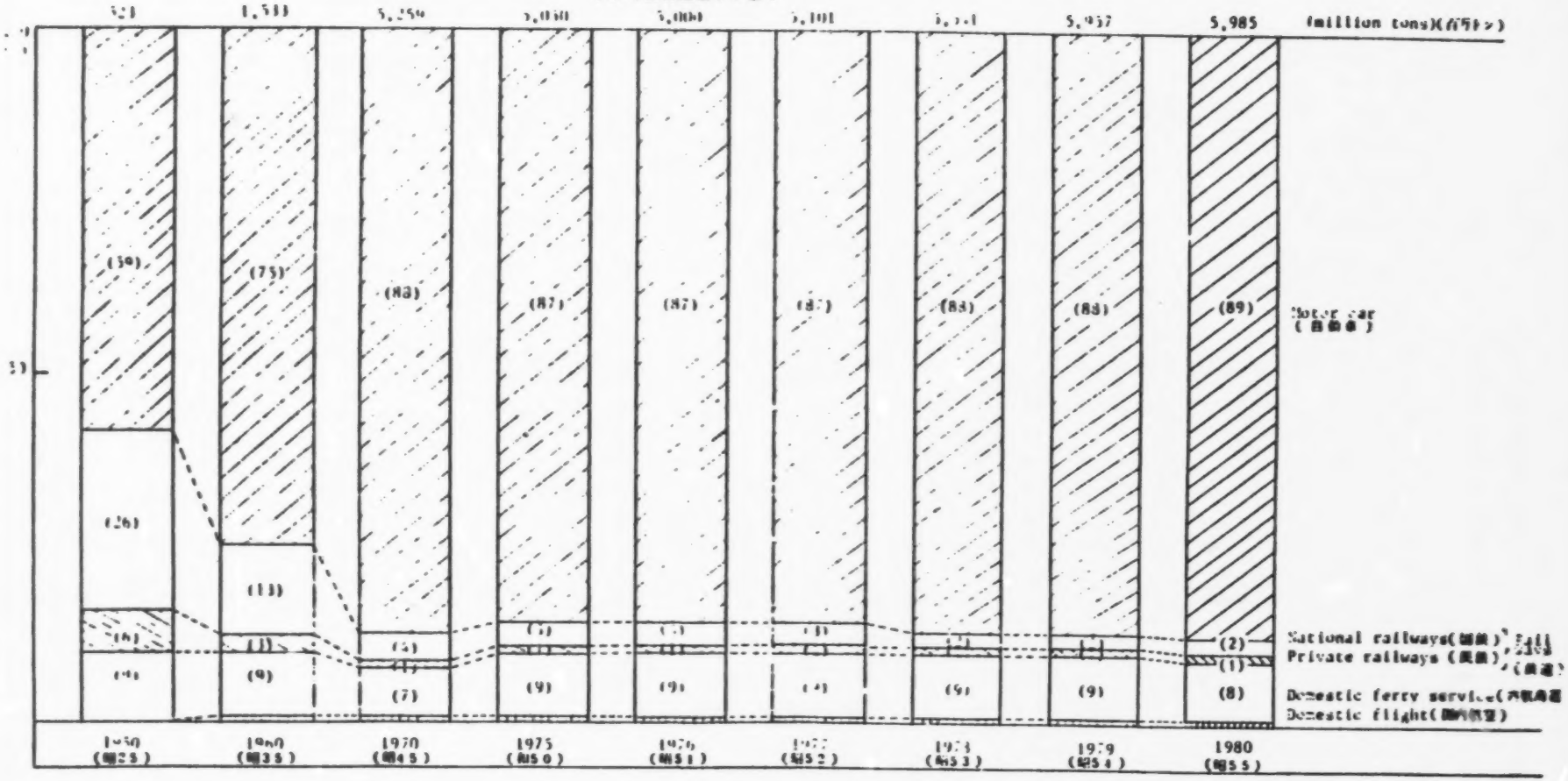
1. Freight

Year	Domestic Freight Transport Tonnage (Unit: Million tons) Total	Motor Cars	Railway Total	Railway National Railways	Railway Private Railways	Domestic Ferry Service	Domestic Flight	Domestic Freight Transport Ton-Kilometer (Unit: 100 million ton kilometers) Total	Motor Cars	Railway Total	Railway National Railways	Railway Private Railways	Domestic Ferry Service	Domestic Flight	Transport Shares (%) Tonnage Motor Cars	Tonnage Railway	Tonnage Domestic Ferry Service	Tonnage Domestic Flight	Ton-Kilometer Motor Cars	Ton-Kilometer Railway	Ton-Kilometer Domestic Ferry Service	Ton-Kilometer Domestic Flight
'50	523	309	165	136	29	49	-	647	54	338	333	5	255	-	59	31	9	-	8	52	39	-
'60	1,533	1,156	238	195	43	139	0.009	1,389	208	545	536	9	636	0.06	75	16	1	0	15	39	46	0
'70	5,259	4,626	256	199	57	377	0.116	3,506	1,359	633	624	10	1,512	0.74	88	5	7	0	39	18	43	0
'75	5,030	4,393	185	142	43	452	0.192	3,609	1,297	474	466	8	1,836	1.52	87	4	9	0	36	13	51	0
'76	5,000	4,356	186	141	45	458	0.203	3,734	1,326	463	455	8	1,943	1.60	87	4	9	0	36	12	52	0
'77	5,101	4,456	175	132	43	470	0.229	3,869	1,431	413	406	7	2,023	1.83	88	3	9	0	37	11	52	0
'78	5,541	4,860	178	133	45	503	0.268	4,095	1,561	412	406	8	2,120	2.24	88	3	9	0	38	10	52	0
'79	5,957	5,258	184	136	48	515	0.315	4,421	1,729	431	423	8	2,258	2.73	88	3	9	0	39	10	51	0
'80	5,985	5,318	167	122	45	500	0.329	4,391	1,789	377	370	7	2,222	2.81	89	3	8	0	41	9	50	0

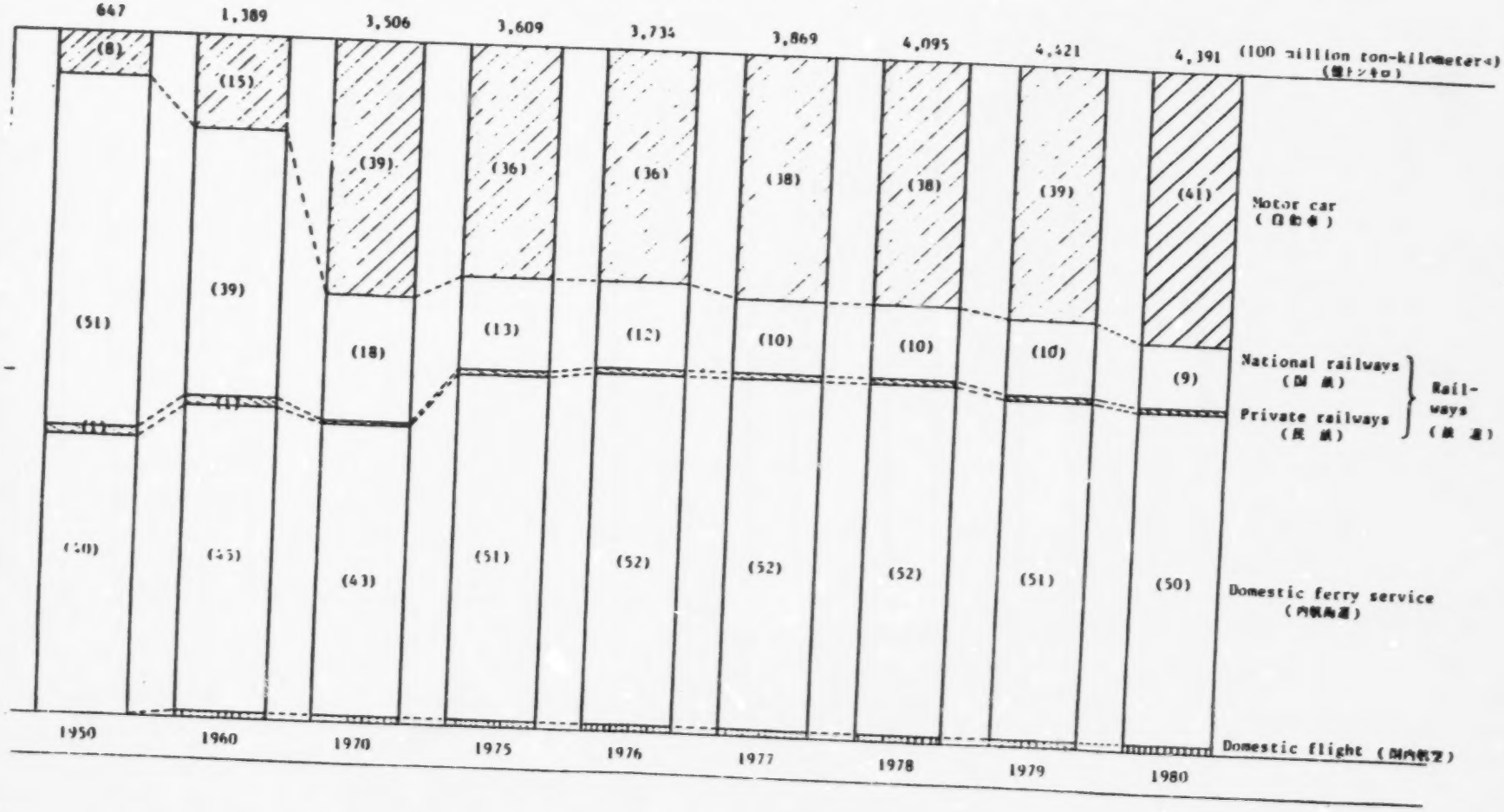
2. Passenger

Year	Passengers Carried (Millions) Total	Motor Cars Buses	Motor Cars Passenger Cars	Railway National Railways	Railway Private Railways	Domestic Ferry Service	Domestic Flight	Passenger-Kilometers (100 million passenger-kilometers) Total	Motor Cars Buses	Motor Cars Passenger Cars	Railway National Railways	Railway Private Railways	Domestic Ferry Service	Domestic Flight	Transport Shares (%) Passengers Motor Cars	Passengers Railway	Passenger-Kilometers Motor Cars	Passenger-Kilometers Railway
'50	9,910	1,393	122	3,001	5,297	97	-	1,172	83	7	691	365	26	-	15	85	8	92
'60	20,291	6,291	1,610	5,124	7,166	99	1.26	2,433	440	115	1,240	604	27	7	39	61	23	77
'70	40,606	11,812	12,221	6,534	9,850	174	15.46	5,871	1,029	1,813	1,897	991	48	93	59	41	50	50
'75	46,195	10,731	17,681	7,048	10,540	170	25.47	7,107	1,101	2,508	2,153	1,085	69	191	62	38	53	47
'76	46,684	10,231	18,679	7,180	10,402	164	28.26	7,095	987	2,643	2,107	1,088	67	201	62	38	53	47
'77	47,567	10,189	19,416	7,068	10,699	162	32.90	7,110	1,046	2,640	1,997	1,126	65	236	62	37	52	44
'78	49,363	9,964	21,446	6,997	10,763	162	37.12	7,474	1,070	2,960	1,958	1,153	64	269	64	36	54	42
'79	51,517	9,967	23,405	6,931	10,907	166	41.36	7,773	1,083	3,149	1,947	1,178	64	302	65	35	55	40
'80	51,720	9,903	23,612	6,825	11,180	160	40.43	7,820	1,104	3,213	1,931	1,214	61	297	65	35	55	40

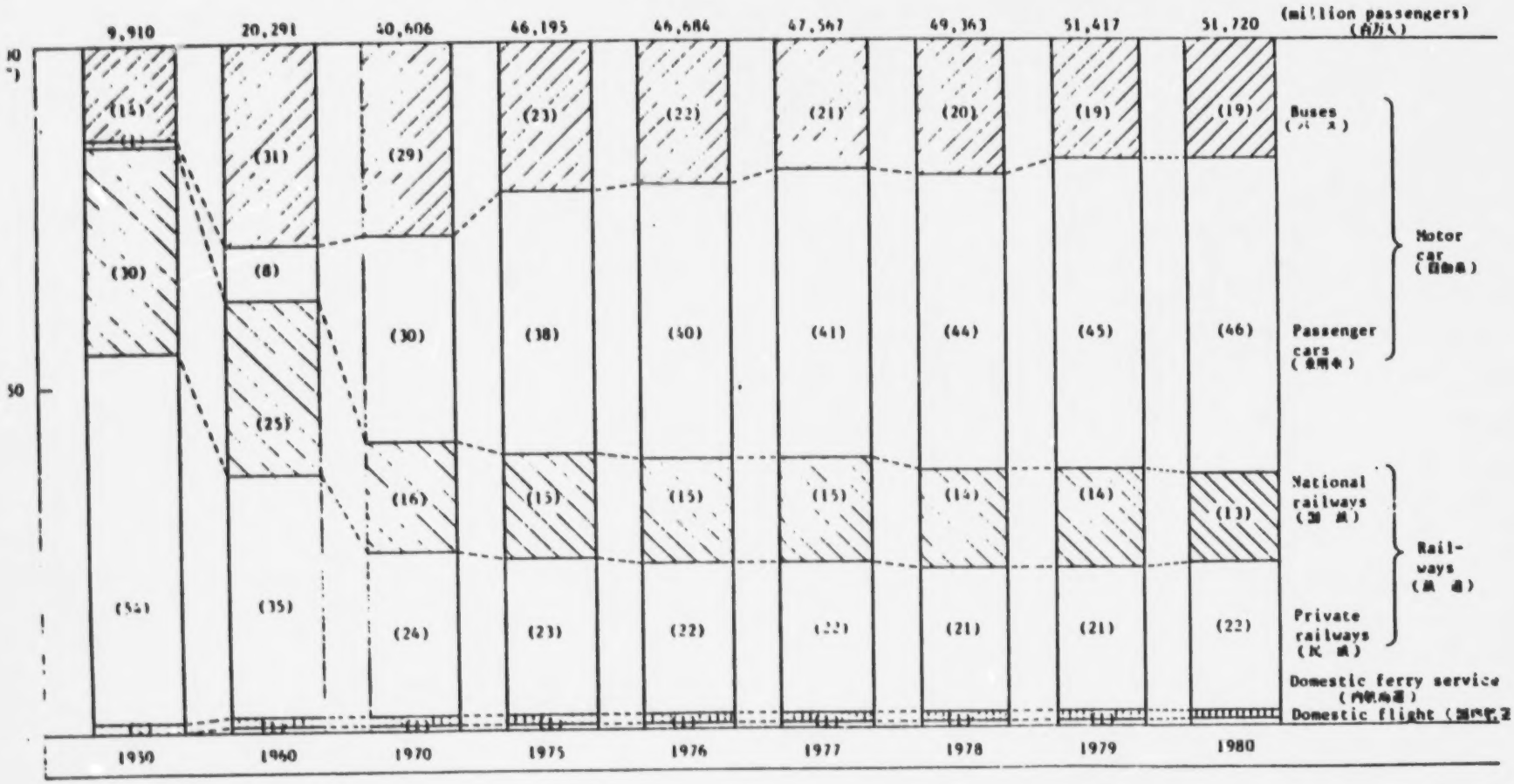
(- 1) Transition of the Traffic Volume by Various Modes of Transport
(輸送機関別輸送量の推移)
(Statistical Data of District Land Transport Bureau)
(陸運統計要覧による)
Domestic Freight Transport Tonnage
(国内貨物輸送トン数)



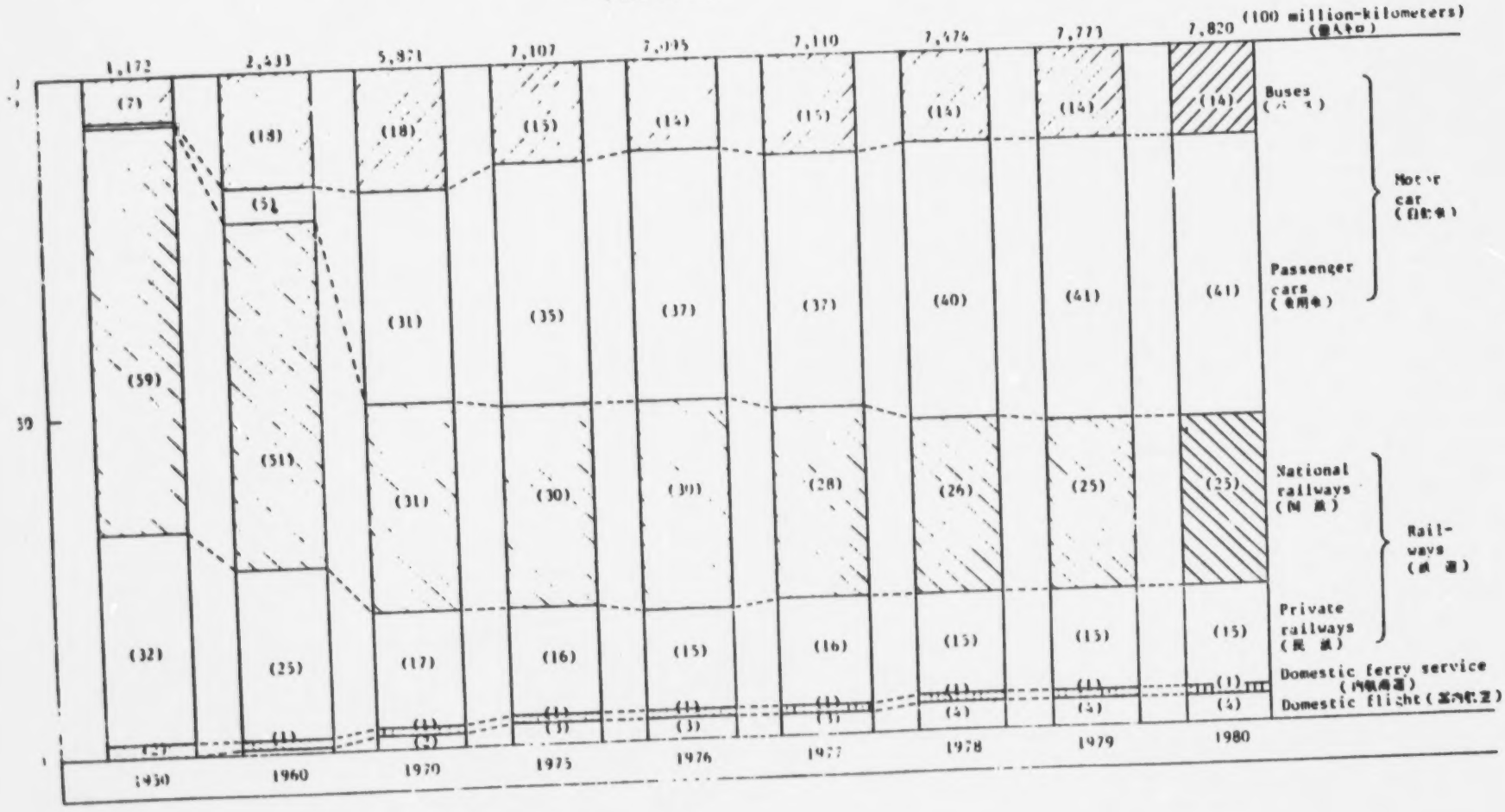
I-(2) Transition of the Traffic Volume by Various Modes of Transport
(輸送機関別輸送量の推移)
(Statistical Data of District Land Transport Bureau)
(陸運統計要覧による)
Domestic Freight Transport Ton-Kilometers
(国内貨物輸送トンキロ)



1-3 Transition of the Traffic Volume by Various Modes of Transport
(輸送機関別輸送量の推移)
(Statistical Data of District Land Transport Bureau)
(陸運統計要覧による)
Passengers Carried
(輸送人員)



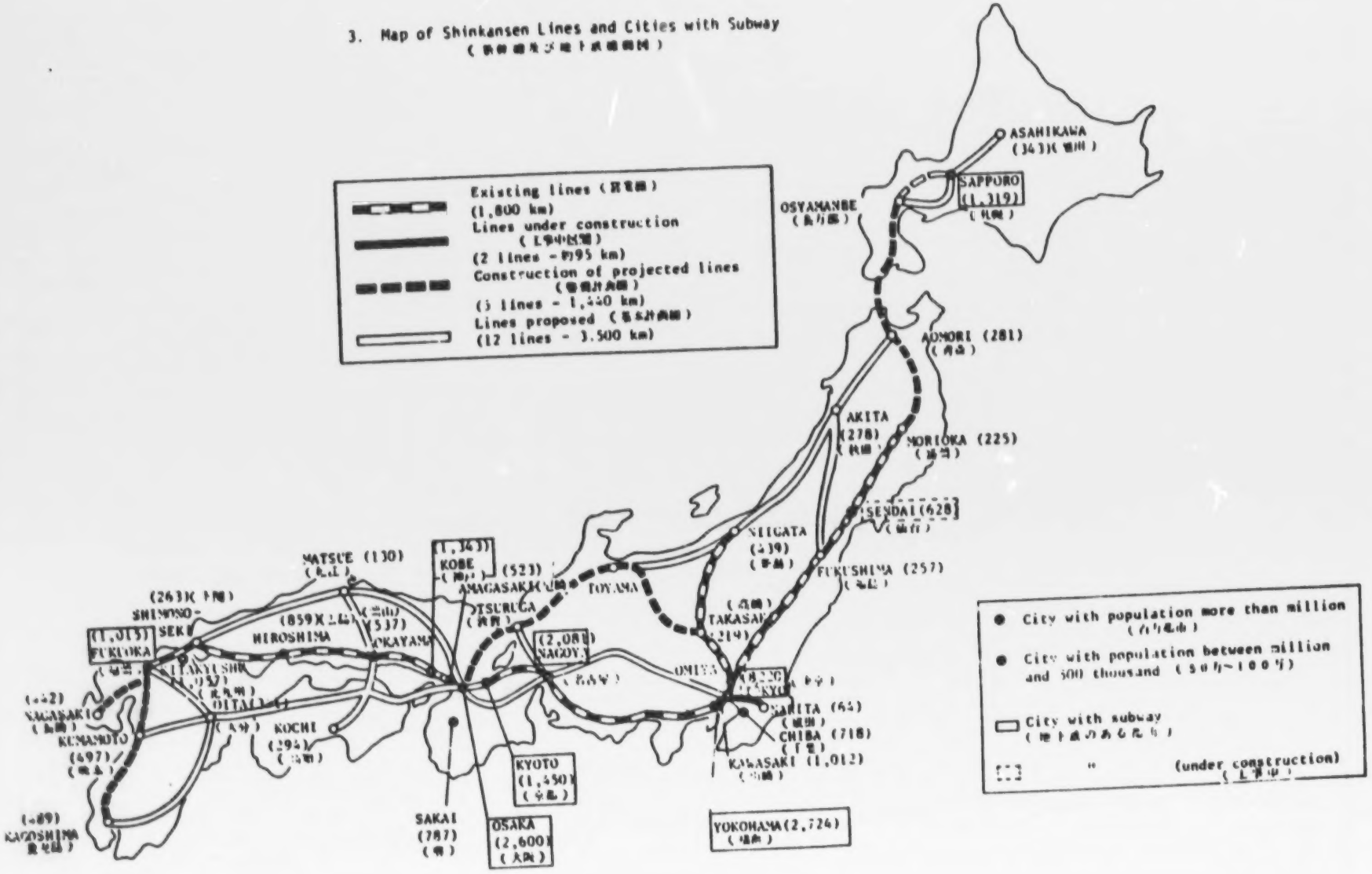
Transition of the Traffic Volume by Various Modes of Transport
(Statistical Data of District Land Transport Bureau)
Passenger-kilometers carried



2. Present State of Railway Service

Year	Kinds of Trains	Route Length・Station Numbers, etc.						Number of Rolling Stock					
		Route Length (Km)	Station Numbers	Employees	Freight Car-km (thousands) (f)	Passengers Car-km (thousands) (f)	Electrified Kilometer (Km)	Steam Locomotive	Electric Locomotive	Diesel Locomotive	Passenger car	Freight car	Total
'55	National	20,093.1	4,572	445,637	4,163,273	1,616,721	1,961	4,897	522	6	14,972	106,223	126,620
	Private	7,578	6,992	125,624	99,992	814,220	-	259	267	110	11,020	10,251	21,907
'60	National	20,754.0	5,160	462,436	5,272,920	2,966,220	4,228	3,164	1,311	469	23,155	139,628	167,727
	Private	7,128	6,479	135,494	102,313	1,312,976	5,893	86	323	207	15,488	9,039	25,143
'70	National	20,890.4*	5,224	459,677	5,447,070	3,714,093	6,020	1,601	1,810	1,266	26,440	147,351	178,468
	Private	6,214	5,082	114,744	86,124	1,578,872	5,383	27	316	198	15,760	4,730	21,031
'75	National	21,271.9	5,296	430,051	4,088,084	4,124,542	7,628	15	2,051	2,203	28,440	120,597	153,306
	Private	5,594	4,446	105,872	58,292	1,754,686	4,902	4	227	206	16,443	2,825	19,705
'76	National	21,276.1	5,230	429,216	4,031,860	4,256,833	7,813	15	2,067	2,190	28,757	115,018	148,047
	Private	5,573	4,382	103,780	58,796	1,783,704	4,918	6	222	203	16,759	2,629	19,819
'77	National	21,304.5	5,293	428,928	3,869,294	4,296,238	7,813	15	2,049	2,207	28,904	109,890	143,065
	Private	5,604	4,361	102,669	65,834	1,834,424	4,929	5	217	207	17,064	2,422	19,915
'78	National	21,306.9	5,294	426,697	3,578,819	4,252,263	8,032	5	1,978	2,160	29,047	101,042	134,232
	Private	5,576	4,242	101,489	54,709	1,866,127	4,901	5	211	203	17,256	2,247	19,922
'79	National	21,322.1	5,296	420,815	3,441,281	4,322,869	8,279	5	1,936	2,125	29,219	99,846	133,131
	Private	5,609	4,263	101,468	54,676	1,915,474	4,924	6	210	206	17,703	2,196	20,321
'80	National	21,321.7	5,294	413,394	3,076,451	4,254,046	8,414	5	1,836	2,109	28,910	99,562	132,442
	Private	5,594	4,222	100,306	50,350	1,957,442	4,907	6	209	201	18,069	2,063	20,548

3. Map of Shinkansen Lines and Cities with Subway



4. Outline of Shinkansen Lines
( )

Item (項目) \ Section (区間)	In Service (営業中)					Under Construction (工事中)
	Tokyo - Shin Osaka (東京・新大阪)	Shin Osaka - Okayama (新大阪・岡山)	Okayama - Hakata (岡山・博多)	Omiya - Niigata (大宮・新潟)	Omiya - Morioka (大宮・盛岡)	Tokyo - Omiya (東京・大宮)
Route length (営業キロ)	515 km	161 km	393 km	270 km	465 km	31 km
Tunnels (トンネル)	69 km (13%)	58 km (36%)	223 km (57%)	106 km (39%)	115 km (23%)	
Bridges (橋りょう)	57 km (11%)	20 km (12%)	31 km (8%)	30 km (11%)	78 km (16%)	
Time required (所要時分)	3 hr 10 min	58 min	2 hr 24 min	1 hr 30 min	3 hr 17 min	20 min
Maximum speed (最高速度)	210 km/h					
Minimum curve radius (最小曲線半径)	2,500 m	4,000 m				
Maximum grade (最急こう配)	20/1,000	15/1,000				
Minimum longitudinal curve radius (縦曲線半径)	10,000 m	15,000 m				
Construction gauge (建築限界)	Height: 7,700 mm (高さ) Width: 4,400 mm (幅)					
Rolling stock gauge (車両限界)	Height: 5,450 mm (高さ) Width: 3,400 mm (幅)					
Rail (レール種別)	60.8 kg/m 1,500 m long-welded rails (長尺レール)					
Track gauge (軌間)	1,435 mm (4'8 1/2")					
Formation width (路盤幅員)	10.7 m	11.6 m	11.0 m	11.6 m		
Distance between track centers (軌道中心間隔)	4.2 m	4.3 m				
Power transmitting system (送電線)	154 kV or 77 kV 2 lines	275 kV or 220 kV 2 lines		275 kV 2 lines		
Feeding system (き電方式)	A.C. 25 kV 60 Hz Single phase (単相) booster-transformer (BT方式)	A.C. 25 kV 60 Hz Single phase (単相) auto-transformer (AT方式)		A.C. 25 kV 50 Hz Single phase (単相) auto-transformer (AT方式)		
Catenary system (電車線方式)	Composite compound	Heavy compound				
Train control (列車制御装置)	ATC (Automatic Train Control) (自動列車制御装置) CTC (Centralized Traffic Control) (列車集中制御装置) COMTRAC (Computer-aided Traffic Control) (コンピュータによる列車制御装置)					
Construction period (工期)	5-1/2 years	5 years	5 years	9 years (Omiya-Morioka)	9 years	13 years
Construction cost (建設費) (billion yen) (1兆円)	380	224	718	1,686	2801	
Opening date (開業年次)	October 1, 1964 (昭39 10 1)	March 15, 1972 (昭47 3 15)	March 10, 1975 (昭50 3 10)	Nov. 15, 1982 (昭57 11 15)	June 23, 1982 (昭57 6 23)	1986

4-(1) Operating Results of Tokaido and Sanyo Shinkansen Lines

（ 東海道・山陽新幹線の営業成績の推移 ）

Item (項目) \ Year (年)	'64	'65	'66	'67	'68	'69	'70	'71	'72 (Note 1) (注)	'73	'74	'75 (Note 2) (注)	'76	'77	'78	'79	'80	'81
Passengers carried (輸送人員) (Millions) (百万人)	11.0	31.0	43.8	55.3	65.9	71.6	84.6	85.4	109.9	128.1	133.2	157.2	143.5	126.8	123.7	123.8	125.6	125.6
Revenues (収入) (Billion Yen) (10億円)	19.4	55.0	89.2	109.8	127.0	164.4	208.6	198.9	251.3	290.3	325.6	477.9	546.7	615.9	652.6	698.9	728.8	788.9
Expenses (支出) (Billion Yen) (10億円)	27.2	67.8	72.8	75.2	77.7	85.7	91.1	90.6	125.1	134.9	168.9	296.0	330.7	370.5	374.3	399.1	430.5	446.6
Balance (収支) (Billion Yen) (10億円)	Δ7.8	Δ12.8	16.4	34.6	49.3	78.7	117.5	108.3	126.2	155.4	156.7	181.9	216.0	245.4	278.3	299.8	298.3	342.3

(Note 1) In March 1972, Sanyo Shinkansen (Shin Osaka - Okayama) was opened.
(注) 昭和47年3月 山陽新幹線（新大阪 - 岡山）開業

(Note 2) In March 1975, Sanyo Shinkansen (Okayama - Hakata) was opened.
(注) 昭和50年3月 山陽新幹線（岡山 - 博多）開業

3. Passenger traffic volume by [illegible] (unit: 10 million persons)
（[illegible]）

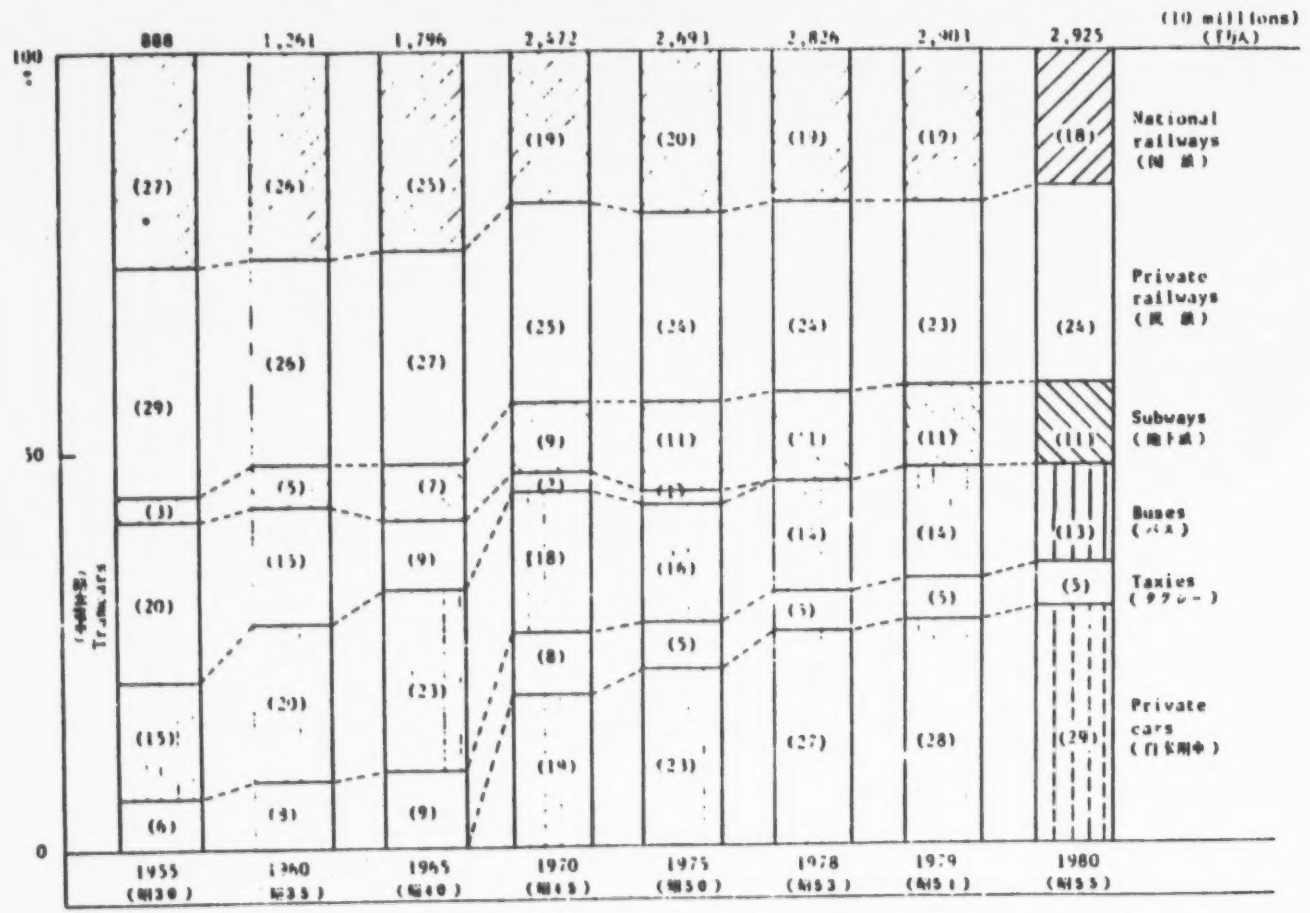
Year	National Railways		Private Railways		Subways		Tram Cars		Buses		Taxies		Private Cars		Total	
	Traffic Volume	%	Traffic Volume	%	Traffic Volume	%	Traffic Volume	%	Traffic Volume	%	Traffic Volume	%	Traffic Volume	%	Traffic Volume	%
1. Metropolitan (Tokyo) Traffic Zone																
'55	186	36	117	23	15	3	84	16	79	15	34	7	-	-	515	100
'60	259	35	175	23	32	4	86	11	144	19	57	8	-	-	751	
'65	347	33	256	26	75	7	68	6	219	21	98	9	-	-	1,063	
'70	360	25	320	22	133	9	18	1	255	17	116	8	256	18	1,458	
'75	407	26	359	23	176	11	5	0	251	16	82	5	307	19	1,587	
'78	411	25	380	23	185	11	6	0	231	14	91	5	348	22	1,662	
'79	411	24	386	23	190	11	6	0	229	14	91	5	390	23	1,701	
'80	394	23	393	23	202	12	6	0	226	14	89	5	397	23	1,705	
2. Chukyo (Nagoya) Traffic Zone																
'55	7	9	25	32	-	-	28	35	16	18	5	6	-	-	79	100
'60	9	8	31	28	2	2	25	21	40	36	9	7	-	-	116	
'65	13	7	45	25	8	5	21	12	73	41	16	9	-	-	176	
'70	17	7	50	20	14	5	10	4	62	24	20	8	82	32	255	
'75	20	7	44	14	26	8	1	0	58	19	16	5	140	45	308	
'78	18	5	47	14	28	8	1	0	52	15	15	5	178	51	339	
'79	18	5	47	13	29	8	1	0	51	15	15	4	197	55	358	
'80	19	5	49	14	30	8	1	0	49	14	15	4	201	55	364	
3. Keihanshin (Kyoto・Osaka・Kobe) Traffic Zone																
'55	44	15	111	39	15	5	68	23	38	13	16	5	-	-	294	100
'60	65	17	126	32	23	6	81	21	68	17	29	7	-	-	392	
'65	90	17	183	33	37	7	67	12	118	21	55	10	-	-	557	
'70	108	14	245	32	77	10	21	3	126	16	57	8	129	17	759	
'75	115	14	237	30	85	11	10	1	121	15	66	8	186	24	769	
'78	112	11	249	29	87	10	5	1	113	14	69	8	220	27	825	
'79	114	14	241	29	88	10	4	0	112	13	69	8	216	26	844	
'80	109	11	245	29	92	11	3	0	113	13	68	8	246	29	856	
4. Total																
'55	237	27	255	29	30	3	180	20	141	15	55	6	-	-	908	100
'60	333	26	332	26	57	5	190	15	252	20	95	8	-	-	1,261	
'65	458	25	486	27	120	7	156	9	410	23	168	9	-	-	1,799	
'70	483	19	615	25	224	9	49	2	461	18	193	8	467	19	2,472	
'75	562	20	645	23	287	11	16	1	410	16	140	5	633	23	2,693	
'78	541	19	666	24	300	11	10	0	396	14	155	5	756	27	2,826	
'79	543	19	674	23	307	11	9	0	392	14	155	5	823	28	2,903	
'80	522	18	687	24	324	11	8	0	388	13	152	5	844	29	2,925	

(Note) '55, '60, '65 do not include the traffic volume of private cars
(注) 昭30、35、40年は自家用自動車の輸送量は含まれない

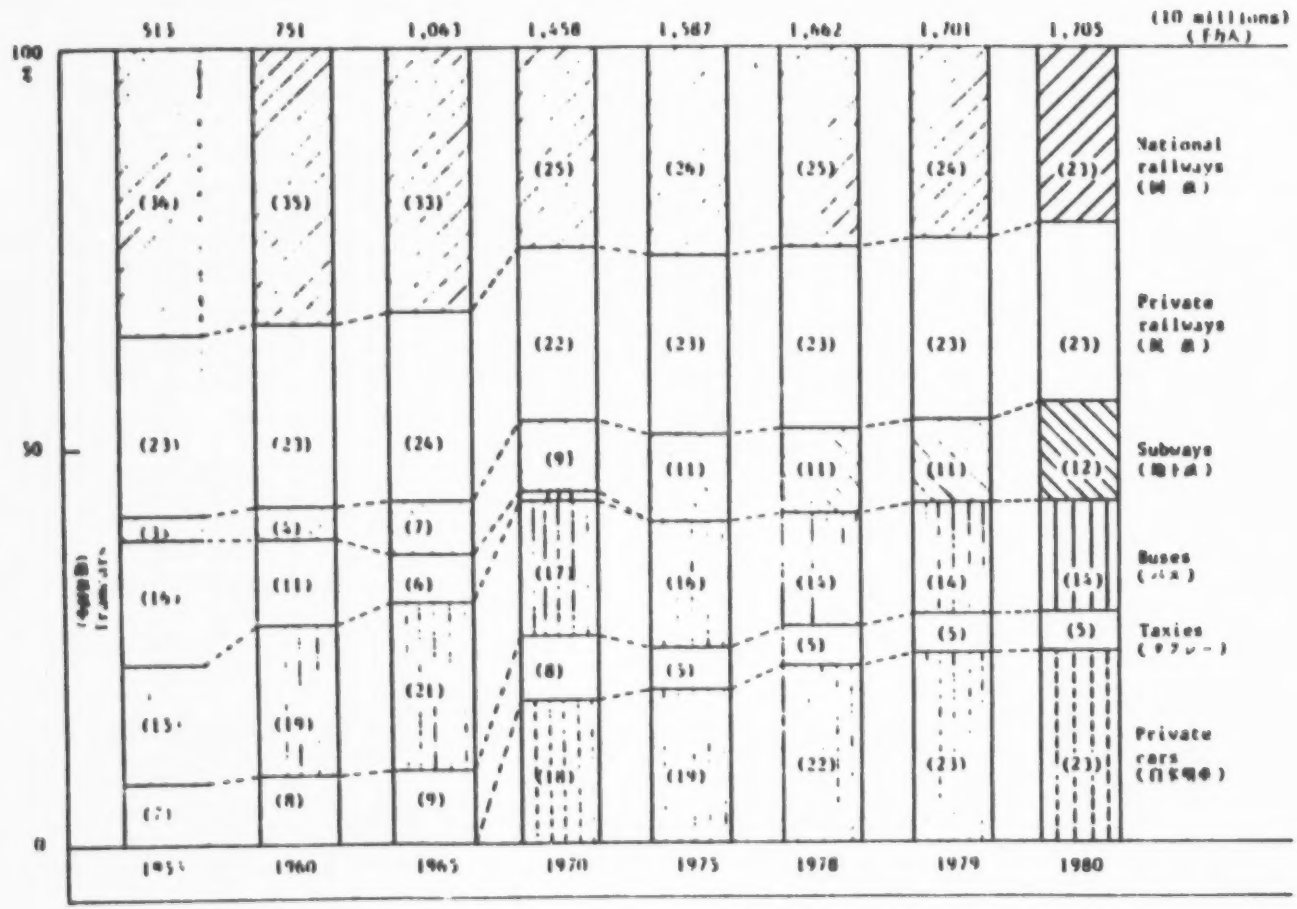
(Urban Traffic Year Book of 1982)
（都市交通年報 昭57年版による）

5-(1) Transition of Traffic Shares of Passengers Carried by Various Modes of Transport

(Three Major Urban Traffic Zones Total)



5-(2) Transition of Traffic Shares of Passengers Carried by Various Modes of Transport
(Metropolitan (Tokyo) Traffic Zone)

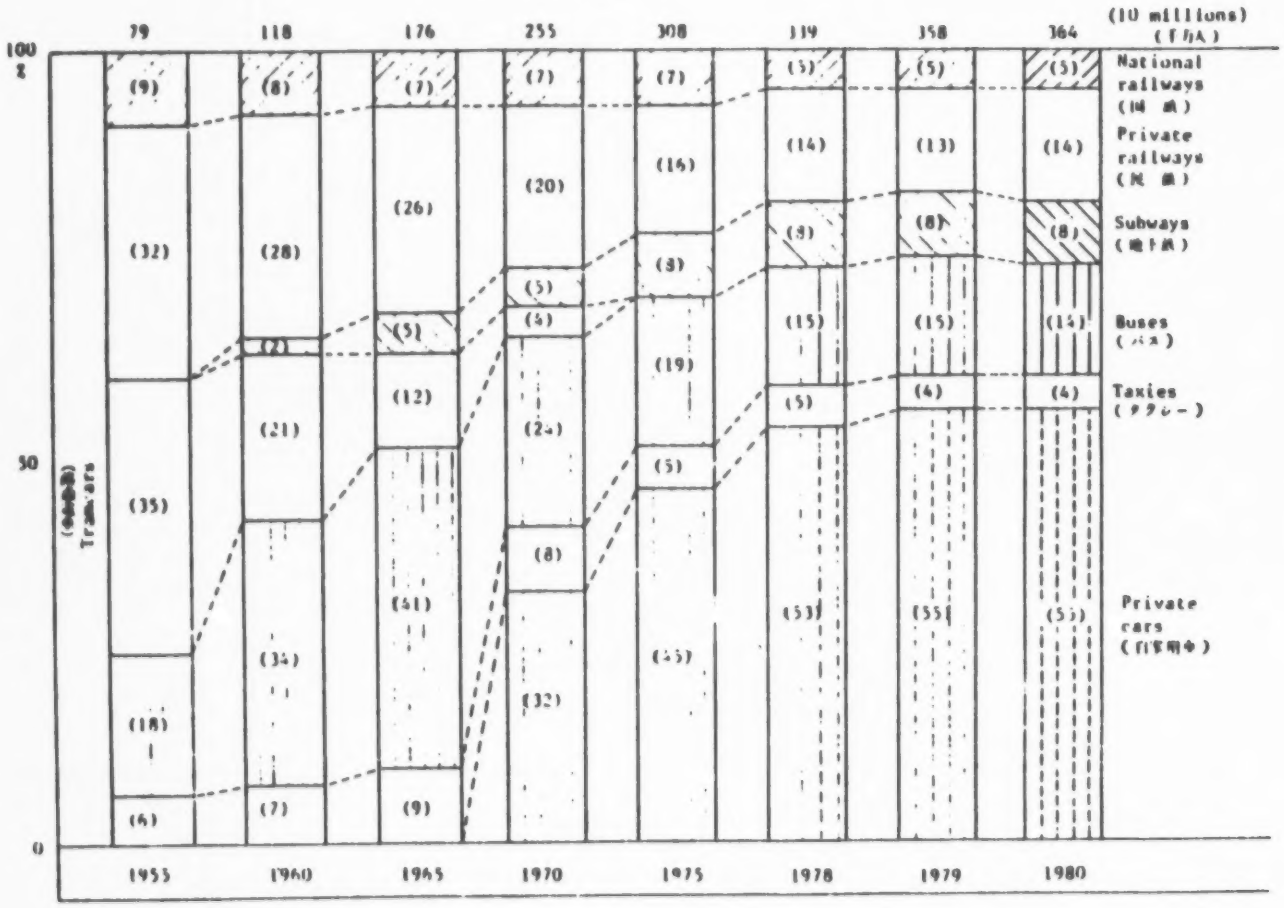


5-(3) Transition of Traffic Shares of Passengers Carried by Various Modes of Transport

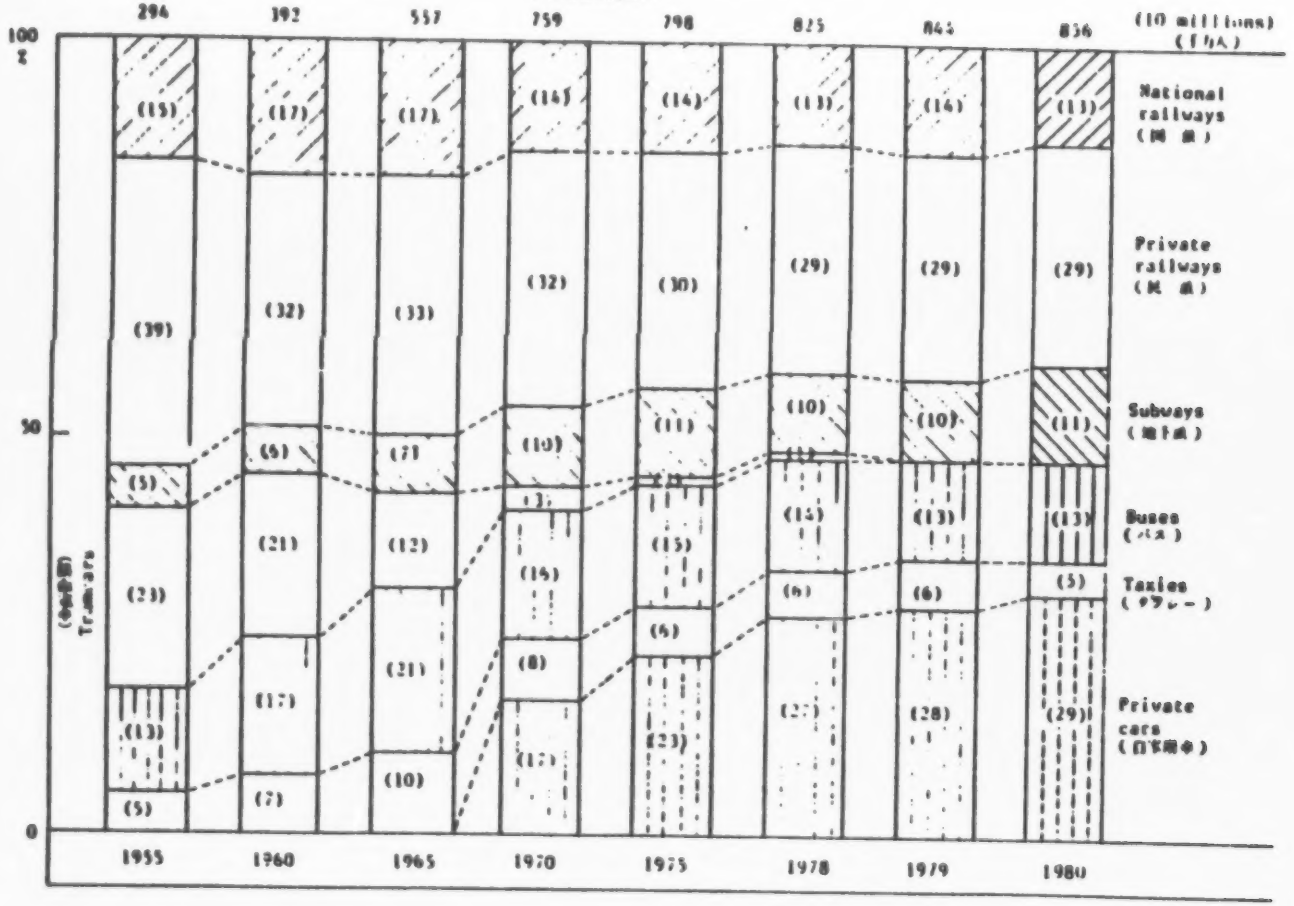
(交通機関別旅客輸送人員分担率の推移)

(Chukyo (Nagoya) Traffic Zone)

(中京(名古屋))



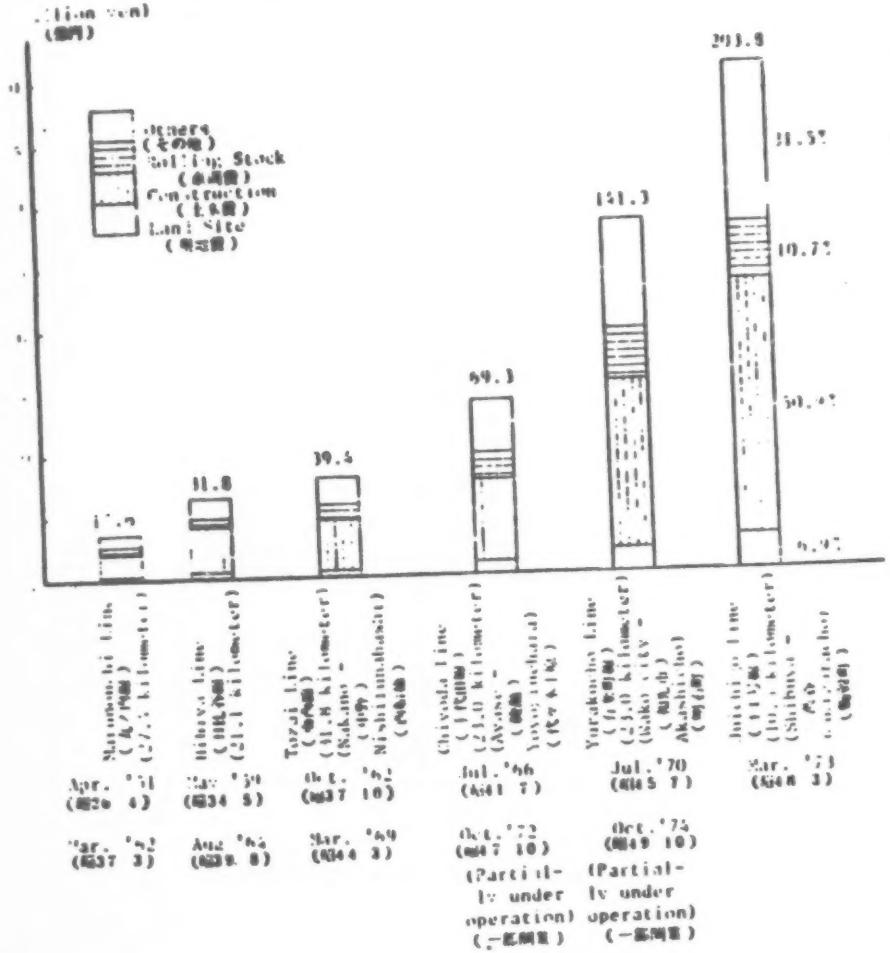
5-(4) Transition of Traffic Shares of Passengers Carried by Various Modes of Transport
(Keihanshin (Kyoto・Osaka・Kobe) Traffic Zone)



6. Outline of Subways (As of August 1, 1981)
（地下鉄の概要）（昭和56年8月1日現在）

Area (地区)	Operator (事業者)	Under Operation (営業中)		Under Construction (工事中)		Scheduled Construction (着手予定)	
		No. of Routes (路線数)	Route Length (Km) (営業キロ)	No. of Routes (路線数)	Construction Kilometer (Km) (建設キロ)	No. of Routes (路線数)	Construction Kilometer (Km) (建設キロ)
Sapporo (札幌)	Sapporo City (札幌市)	2	24.2	1	7.3		
Sendai (仙台)	Sendai City (仙台市)			1	14.4		
Metropolitan Area (首都圏)	Metropolitan High Speed Transportation Corporation (帝都高速度交通営団)	7	131.8	3	17.2	2	7.3
	Tokyo-to (東京都)	3	54.9	1	9.2	2	40.3
	Yokohama City (横浜市)	2	11.5	2	10.6	1	1.9
Chukyo (中京)	Nagoya City (名古屋市)	4	51.5	2	10.1		
Kei-Hanshin (京阪神圏)	Kyoto City (京都市)	1	6.6	1	5.1		
	Osaka City (大阪市)	6	86.1	4	12.5	3	9.2
	Kobe City (神戸市)	1	5.7	1	7.5		
Kyushu (九州)	Fukuoka City (福岡市)	1	5.8	2	9.6		
Total (計)		27	378.1	18	103.5	8	58.7

Transition of Construction Cost of Subways per Kilometer
（地下鉄キロ当り建設費の推移）



3. Subsidies to Subways
（地下鉄に対する助成制度）

1. Subsidize the amount equivalent to 70% of construction cost in ten year installments, starting from the following year.
（補助対象建設費の額の７０％に相当する金額を翌年度から１０年分割補助する。）

2. The subsidy is shared fifty fifty by the State and local public bodies.
（負担は国と地方公共団体と折半とする）

3. Subsidy Calculation Method
（補助金算定方式）

(1) Construction of a new line
（新線建設）

$$\text{Construction Cost for Subsidy (補助対象建設費)} \left\{ \left(\text{Total Construction Cost (総建設費)} - \text{Overhead (諸雑費)} \right) \times 0.9 \left(\text{onerous capital ratio (有償資金比率)} \right) \right\} \times 0.7 \text{ (subsidy ratio) (補助率)}$$

(2) Improvement
（改良工事）

$$\text{Construction Cost for Subsidy (補助対象建設費)} \left\{ \left(\text{Total Construction Cost (総建設費)} - \text{Overhead (諸雑費)} \right) \times \text{onerous capital ratio (有償資金比率)} \right\} \times 0.7 \text{ (subsidy ratio) (補助率)}$$

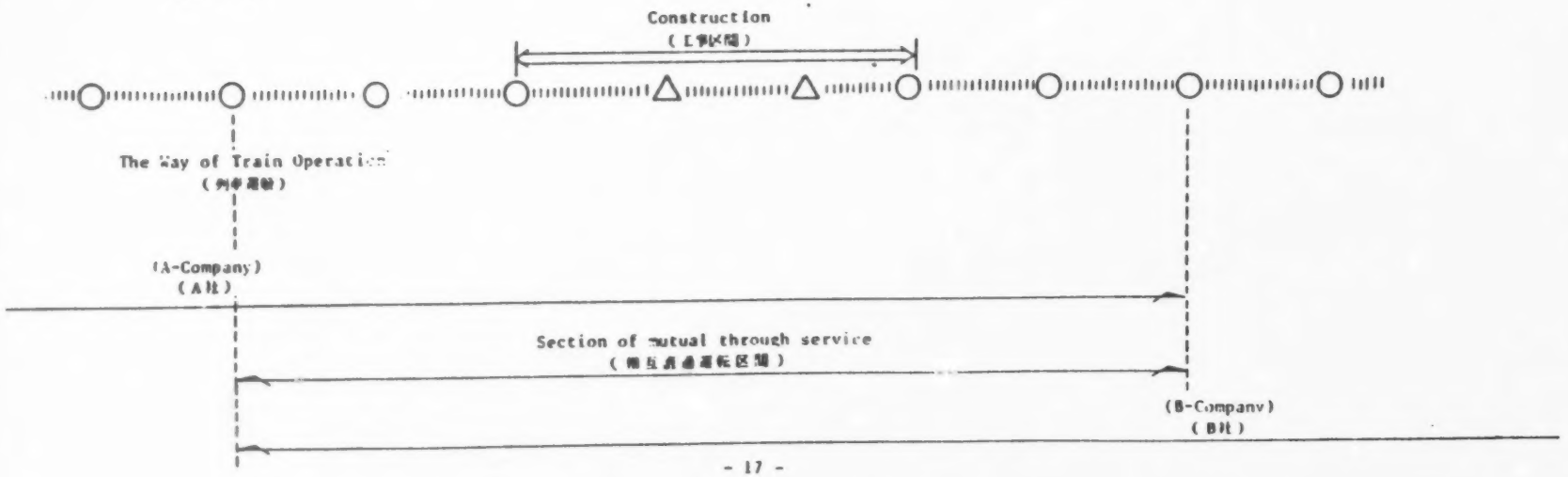
4. Subsidy Ratio
（補助率）

Year (年)	1	2	3	4	5	6	7	8	9	10	Total (計)
State (国)	6	5	4	3	3	3	3	3	3	2	35%
Local Public Body (地方公共団体)	6	5	4	3	3	3	3	3	3	2	35%

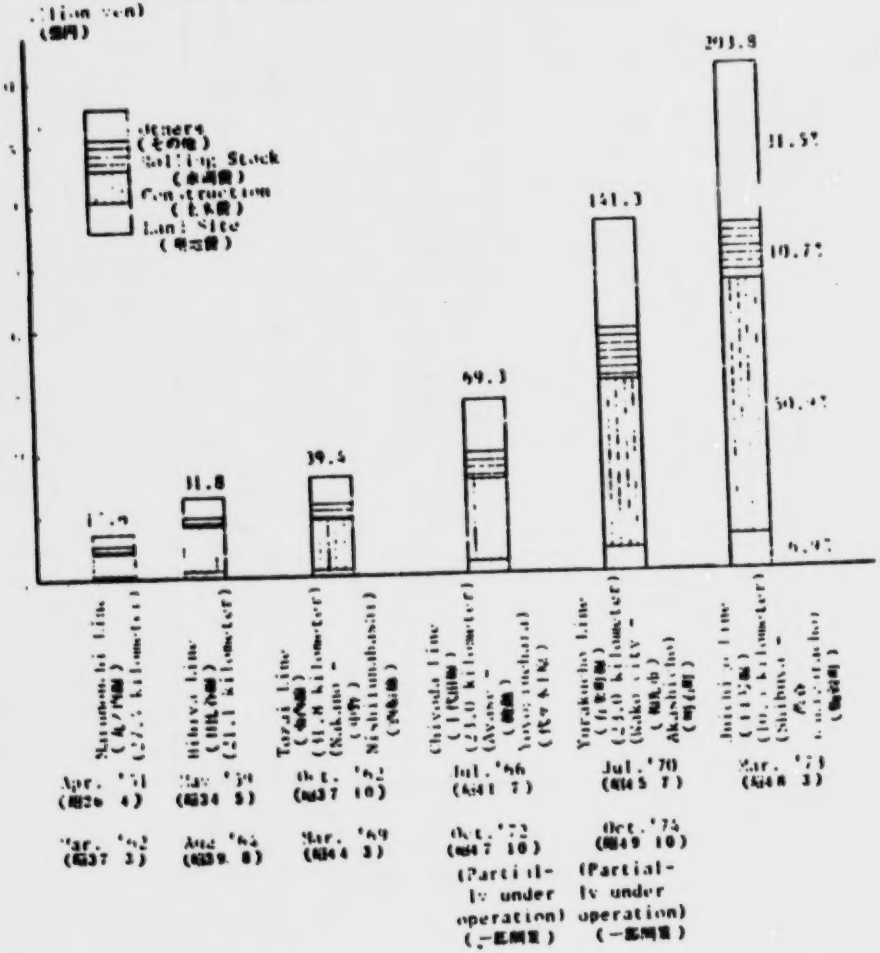
9. Mutual Through Service
（相互通通運転）

(1) Before Construction
（工事前）

(2) After Construction
（工事終了後）



Transition of Construction Cost of Subways per Kilometer
(地下鉄キロ当り建設費の推移)



3. Subsidies to Subways
(地下鉄に対する補助制度)

1. Subsidize the amount equivalent to 70% of construction cost in ten year installments, starting from the following year.
(補助対象建設費の額の70%に相当する金額を翌年度から10年分割補助する。)

2. The subsidy is shared fifty fifty by the State and local public bodies.
(負担は国と地方公共団体と折半とする)

3. Subsidy Calculation Method
(補助金算定方式)

(1) Construction of a new line
(新線建設)

$$\text{Construction Cost for Subsidy (補助対象建設費)} \left\{ \left(\text{Total Construction Cost (総建設費)} - \text{Overhead (諸雑費)} \right) \times 0.9 \left(\text{onerous capital ratio (有償資金比率)} \right) \right\} \times 0.7 \text{ (subsidy ratio) (補助率)}$$

(2) Improvement
(改良工事)

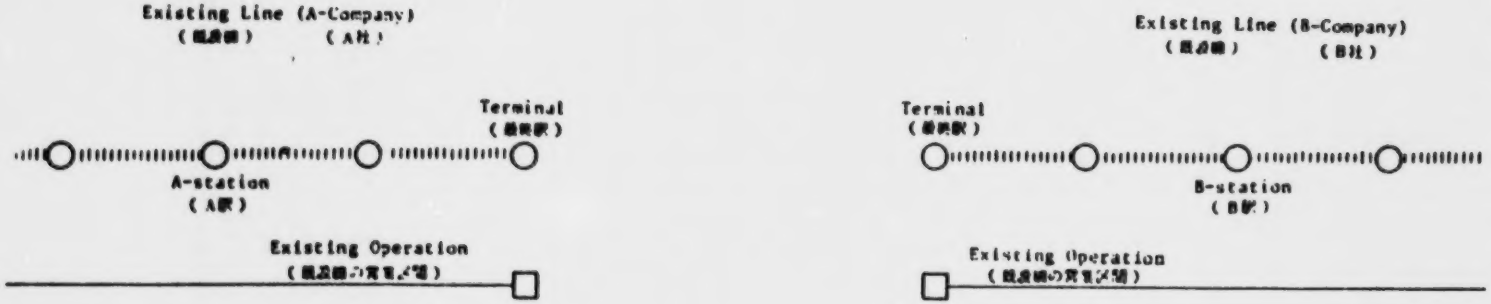
$$\text{Construction Cost for Subsidy (補助対象建設費)} \left\{ \left(\text{Total Construction Cost (総建設費)} - \text{Overhead (諸雑費)} \right) \times \left(\text{onerous capital ratio (有償資金比率)} \right) \right\} \times 0.7 \text{ (subsidy ratio) (補助率)}$$

4. Subsidy Ratio
(補助率)

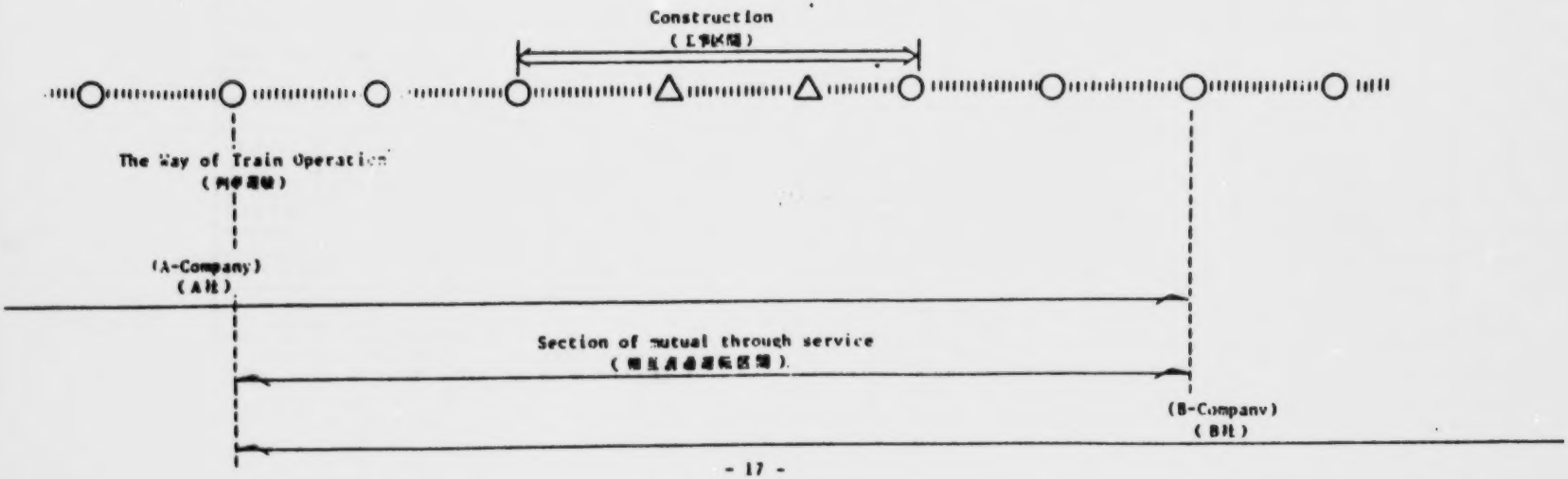
Year (年)	1	2	3	4	5	6	7	8	9	10	Total (計)
State (国)	5	5	4	3	3	3	3	3	3	2	35%
Local Public Body (地方公共団体)	5	5	4	3	3	3	3	3	3	2	35%

9. Mutual Through Service
（相互直通運転）

(1) Before Construction
（工事前）



(2) After Construction
（工事完了後）



10. Outline of Monorail (As of August 1981)

(モノレールの概要)　　(昭56 8 現在)

Classification (区分)		Under Operation (営業中)				
Type (方式)		Hanging Type (懸垂式)		Straddle Type (跨座式)		
Operator (事業者名)		Shonan Monorail (湘南モノレール)	Tokyo Metropolitan Government (都営)	Tokyo Monorail (東京モノレール)	Odakyu Electric Railway (小田急電鉄)	Nagoya Railway (名古屋鉄道)
Operation Started (開業)	Year and Month (年月)	March 1970, (昭45 3) July 1971 (昭46 7)	December 1957 (昭32 12)	September 1964 (昭39 9)	April 1966 (昭41 4)	March 1962 (昭37 3)
Operating Section (区間)		Ofuna - (大船) Shonan Enoshima (湘南江の島)	Haneda Dobutsuen - (羽田空港) Suneo (すの尾)	Hamada (浜松) - Monorail Hamamatsucho (モノレール浜松町)	Nakagaeba Yuen - (中ノ郷遊園) Nakagaeba Yuen Seimon (中ノ郷遊園正門)	Inuyama Yuen - (犬山遊園) Dobutsuen (動物園)
Route Length* (Km) (キロ程)		6.6	6.3	13.0	1.1	1.2
Classification of Single Track or Double Track (単・複線の別)		Single track (単線)	Single track (単線)	Single tracked near terminal stations. Rest is double tracked. (始発駅付近のみ単線・他は複線)	Single track (単線)	Single track (単線)
Number of Rolling Stock (車両数)		16	2	44	2	6
Average seating capacity per Vehicle (person) (一車当平均定員)		104	31	127	120	65
Number of Times Operated per Day (going and Returning) (一日往復回数(往復))		99	Regular (定期) 7 Irregular (不定期) 56	132	Regular (定期) 25 Irregular (不定期) 28	17
Headway (運転間隔)	Peak hours (ピーク時) Off peak hours (オフピーク時)	7'30" 15 00"	Irregular Operation (不定期運行)	5'30" 7'00"	Irregular Operation (不定期運行)	Irregular Operation (不定期運行)
Maximum Running Speed (最高運転速度) (Km/h)		75	15	80	40	35
Passengers carried (輸送人員)	1979, 1980 (昭54)(昭55) With commuter passes (定期) (thousand person) (千人)	3,910, 4,154	- -	7,377 7,753	- -	- -
	Without commuter passes (定期外) (thousand person) (千人)	3,711, 3,762	1,050, 1,150	19,029, 18,786	661, 694	987, 928
	Total (計)	7,621, 7,916	1,050, 1,150	26,406 26,539	661, 694	987, 928

Classification (区分)	Under Operation (営業中)				
Type (型式)	Hanging Type (懸垂式)		Straddle Type (跨座式)		
Operator (事業者名)	Shonan Monorail (湘南モノレール)	Tokyo Metropolitan Government (都営)	Tokyo Monorail (東京モノレール)	Odakyu Electric Railway (小田急電鉄)	Nagoya Railway (名古屋鉄道)
Construction Cost per Kilometer (one hundred million yen) (キロ当建設費) (億円)	8	-	16	1.8	4
Minimum Curve Radius in the Main Track (m) (本線最小曲線半径)	50	40	120	40	150
Maximum Grade in the Main Track (0/00) (本線最大こう配)	74	40	60	54	97
Type of Electric Railway (電気鉄道の方式)	1,500 V, D.C.	600 V, D.C.	750 V, D.C.	600 V, D.C.	1,500 V, D.C.
Classification of ATS or ATC (ATS・ATCの別)	ATS	ATS	ATS	ATS	ATS
Installation of Train Radio (列車無線の有無)	Space Wave Radio (空間波無線)	-	Space Wave Radio (空間波無線)	Space Wave Radio (空間波無線)	Inductive Radio (誘導無線)

Classification (区分)		Under Construction (建設中)	Scheduled Construction (建設予定中)		
Type (形式)		Straddle Type (跨座式)	Hanging Type (懸垂式)	——	——
Construction-Operating Body (建設・経営主体)		Kitakyushu High Speed Railway (北九州高速鉄道)	Chiba City Monorail (千葉都市モノレール)	Osaka High Speed Railway (大阪高速鉄道)	Third Sector is scheduled with Okinawa Pref. as main body. (沖縄県を主とする第三セクターを予定)
Completion Schedule (完成予定)	Year and Month (年月)	April 1983 (昭和58年4月)	Partial Operation Mar. 1986 (一部開業 昭和61年3月) Full Operation April 1987 (全線 昭和62年4月)	Partial Operation Apr. 1985 (一部開業 昭和60年4月) Full Operation Apr. 1988 (全線 昭和63年4月)	1989 (昭和64年)
Operating Section (区間)		Kokura Station - Shichikonnae (小倉駅 - 七光ヶ浦)	Chuoko - Hoshibuki (中央通 - 星久喜) Chiba St. - Chishirodai (千葉駅 - 千城台)	Osaka Int'l Airport - Hankyu Minami Ibaragi (大阪国際空港 - 阪急南茨木)	Takashima - Toriberi (高島 - 鳥居)
Route Length (Km) (営業キロ)		8.7	3.4 + 12.1 = 15.5	13.7	11.1
Classification of Single Track or Double Track (単・複線の別)		Double Track (複線)	Double Track (複線)	Double Track (複線)	-
Number of Rolling Stock (Vehicle) (車両数)	(両)	60 (72 in the future) (将来は72両)	364	64	-
Seating Capacity per Vehicle (車両定員) (person) (人)		Head car 114 (先頭車) Middle car 125 (中間車)	Head car 101 (先頭車) Middle car 112 (中間車)	-	-
Headway (運転間隔)	Peak hours (ピーク時)	At time of operation start 6' (1995 3') (運転開始時)	At time of operation start 3'-6' (2005 4'20") (運転開始時 3分～6分)	At start time of Partial Operation 7'30" (一部開業時 7分30秒) Full Operation 6'42" (全線開業時 6分42秒)	-
	Off peak hours (ピーク外)	10'	10'-15'		
Passengers Carried (輸送人員) (Person) (人)	Operation Completion Year (営業完了年度)	1995 : 122,300/day (1万2千人)	2005 : 174,652/day (17万5千人)	1989 : 104,433/day (10万4千人)	1990 : 71,751/day (7万5千人)
	Peak Hours (ピーク時)	10,200/hour	11,415/hour	5,647/hour	-

Classification (区分)		Under Construction (建設線)	Scheduled Construction (建設予定線)		
Type (型式)		Straddle Type (跨座式)	Hanging Type (懸下式)	——	——
Construction-Operation Body (建設・経営主体)		Kitakyushu High Speed Railway (北九州高速鉄道)	Chiba City Monorail (千葉都市モノレール)	Osaka High Speed Railway (大阪高速鉄道)	Third Sector is scheduled with Okinawa Pref. as main body. (沖縄県を主体とする第三セクターを予定)
Construction Cost (建設費)	Disbursed by Operator (事業者負担分)	31,920 million yen (百万円)	66,305 million yen (百万円)	40,203 million yen (百万円)	34,700 million yen (百万円)
	Public Enterprises, etc. (公共事業等)	27,631	53,708	39,681	28,300
	Total (計)	59,551	120,013	79,884	63,000
	per kilometer (キロ当り)	6,845	7,800	5,831	5,700
Minimum Curve Radius in the Main Track (m) (本線最小曲線半径)		80	50	-	-
Maximum Grade in the Main Track (0/00) (本線最急勾配)		40	40	-	-
Type of Electric Railway (電気鉄道の方式)		1,500 V, D.C.	1,500 V, D.C.	-	-
Classification of ATS and ATC (ATS・ATC区分)		ATC	ATC	-	-
Installation of Train Radio (列車無線の有無)		Space Wave Radio (空間波無線)	Space Wave Radio (空間波無線)	-	-

11. Outline of New People Mover System
（新交通システムの概要）

Classification (区分)		Under Operation (営業中)		Under Construction (建設中)	Construction to be started (着工予定線)		Construction Scheduled (建設予定線)	
Operator (事業者名)		Osaka City (大阪市)	Kobe Shin Kotsu (神戸新交通)	Yamanashi (山梨)	Tobu Hokkaido Shinkotsu (東武北海新交通)	Saitama Shin Toshi Kotsu (埼玉新都市交通)	Under Study mainly by Yokohama City (横浜市を中心に検討中)	Under Study mainly by Ibaraki Pref. (茨城県を中心に検討中)
Type (型式)		Side-Guided Type (側方案内式)	Side-Guided Type (側方案内式)	Center-Guided Type (中央案内式)	Center-Guided Type (中央案内式)	Side-Guided Type (側方案内式)	Side-Guided Type (側方案内式)	Under study, including Dual Mode Bus System (デュアルモードバスシステムを含めて検討中)
Completion Schedule (完成予定)	Year and Month (年月日)	March 10,1981 (昭56 3 10)	Feb. 5, 1981 (昭56 2 5)	Partial Operation Nov 1982 (一部開業 昭57 5) Full Operation April 1983 (全線開業 昭57 3)	-	Oct. 1982 (昭57 10)	-	-
Operating Section (区間)		Nakafuto - (中埠頭) Suminoe Koen (住之江公園)	Sannomiya - (三宮) Minami Koen (南公園)	Yukarigaoka - (ゆりがおか) Koen (公園)	Meitetsu Komaki (名鉄小牧) - Tobuoui Higashi (東武竹ノ塚)	Omiya - Kohari (大宮) (小針)	JNR Shinsugita (国鉄新杉田) - Keihyu Kanazawa Hakkei (京急金沢八景)	Tsukuba Univ. Annex Hospital - (筑波大学附属病院) Kenkenmura Bus Center (県南バスセンター)
Route Length (Km) (営業キロ)		6.9	6.4	4.2	7.7	12.9	10.0	1.5
Classification of Single or Double Track (単・複線の別)		Double Track (複線)	Double Tracked portion 2.9Km (複線部) Single Track loop portion 3.5Km (単線ループ部)	Single Track (単線)	Double Track (複線)	Double Track 8.3 Km (複線) Single Track 4.6 Km (単線)	Double Track (複線)	Double Track (複線)
Number of Rolling Stock (Vehicle) (車両数, (両))		52 (112 in future) (将来)	78	9	28	60	-	-
Average seating capacity per vehicle (一両あたり定員, (person) (人)		75	75	70	70	75	-	-
Headway (運転時隔)	Peak hours (ピーク時)	3'30" - 2'15"	3'20" - 2'30"	7'	7'30" - 2'40"	7'30"	-	-
	Off peak hours (オフピーク時)	5'	5'	14'	10' - 5'	15'	-	-
Maximum Running Speed (最高運転速度) (km/h)		50	57	50	50	60	-	-

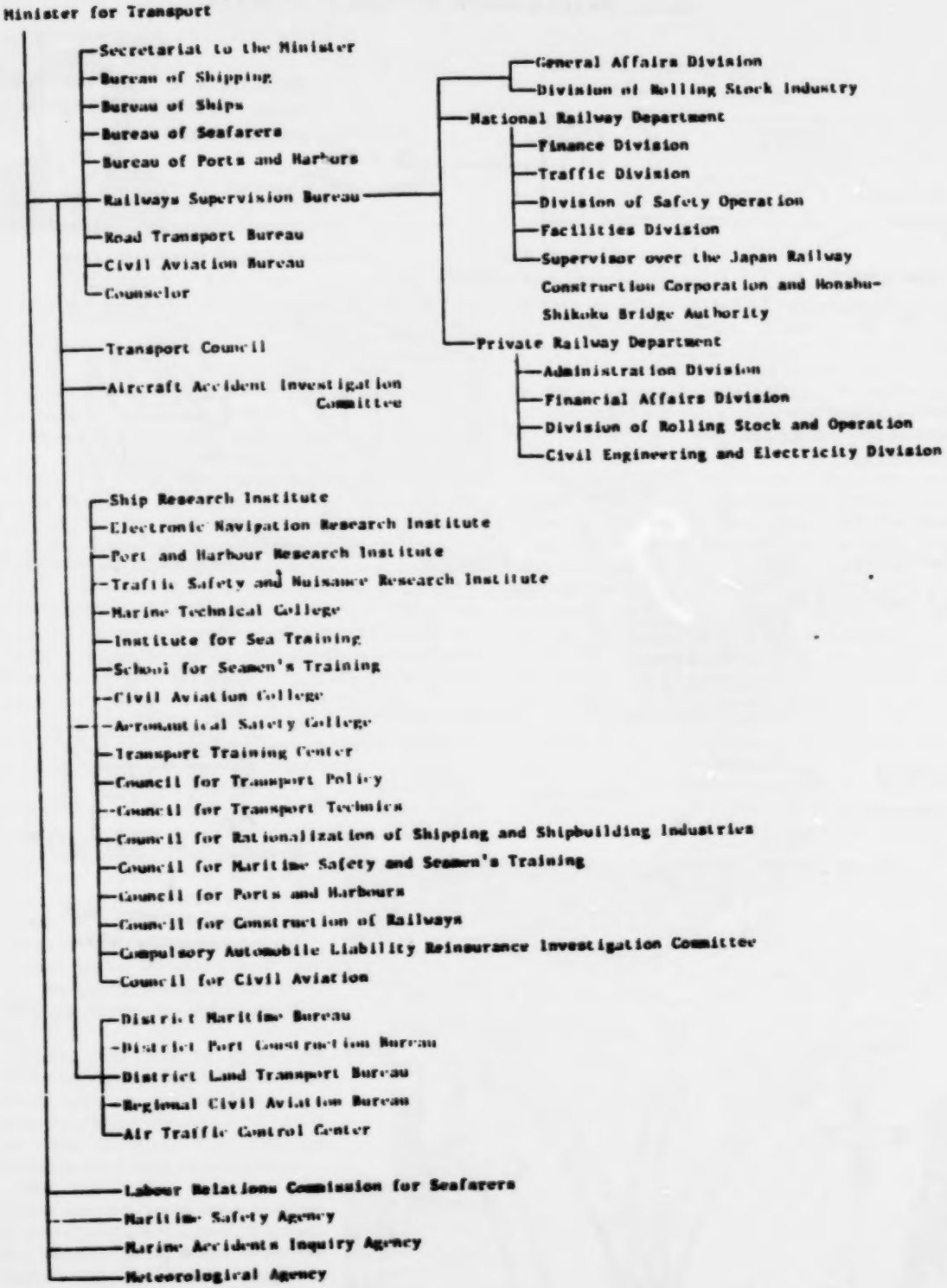
Classification (区分)		Under Operation (営業中)		Under Construction (建設中)	Construction to be started (着工予定線)		Construction Scheduled (建設予定線)	
Operator (事業者名)		Osaka City (大阪市)	Kobe Shin Kotsu (神戸新交通)	Yamaman (山万)	Tokaisi Shinkotsu (東海新交通)	Saitama Shin Toshi Kotsu (埼玉新都市交通)	Under Study mainly by Yokohama City (横浜市を中心に検討中)	Under Study mainly by Ibaragi Pref. (茨城県を中心に検討中)
Passengers Carried (輸送人員) (Person) (人)	Operation Completion Year (営業完了年次) Peak Hours (ピーク時)	1990: (昭和65) 72,000/day 13,000/hour	1985: (昭和60) 68,500/day 10,300/hour	1985: (昭和60) 17,000/day 2,000 hour	1990: (昭和65) 31,000/day 6,300 hour	1991: (昭和66) 47,000/day 5,000/hour	1985: (昭和60) 95,000/day -	- -
Construction Cost (建設費)	Disbursed by Operator (事業者負担分)	210 hundred million yen (億円)	222 hundred million yen (億円)	20 hundred million yen (億円)	136 hundred million yen (億円)	31 hundred million yen (億円)	-	-
	Public Enterprises, etc. (公共事業等)	190	215	-	109	245 hundred million yen by National Railways (国鉄) (億円) 25 hundred million yen municipality (自治体) (億円)	-	-
	Total (計)	420	437	20	245	301	-	-
	per kilometer (キロ当り)	41	68	4.9	32	23	-	-
Minimum Curve Radius in the Main Track (m) (本線最小曲線半径)		70	30	40	100	25	-	-
Maximum Grade in the Main Track (0/00) (本線最急勾配)		35	50	65	60	60 (down Grade) (下り) 55 (up ") (上り)	-	-
Turnout System (分岐方式)		Movable Guide plate system (可動案内軌方式)	Up and down system (台代式)	Pin-joint system (ピンジョイント式)	Pin-joint system (ピンジョイント式)	Movable Guide plate system (可動案内軌方式)	-	-
Type of Electric Railway (電気鉄道の方式)		600 V, 3φA.C.	600 V, 3φ A.C.	750, D.C.	-	600 V, 3φ A.C.	-	-
Braking System (制動の方式)		ATO, ATC	ATO, ATC	ATS	ATO, ATC	ATC	-	-
Remarks (備考)		Future Target: Unmanned Operation (将来は無人運転を予定)	Future Target: Unmanned Operation (将来)	One-man Operation is scheduled (ワンマン運転を予定)	Future Target: Unmanned Operations (将来は無人運転を目標)	One-man Operation is scheduled (ワンマン運転を予定)	One-man Operation is scheduled (将来)	-

12. Comparison of Shinkansen and French TGV
（新幹線とTGVの比較）

October 1981

Comparison Item (比較項目)	Japanese Shinkansen (新幹線)	French TGV (TGV)	Remarks (備考)
1. Transport volume (輸送量)			
(1) Transport volume per day (一日の輸送量)	About 340,000 persons (Maximum in the past: 1,400,000) (過去の最大)	About 9,000 persons	
(2) Transport volume per train (一列車の輸送量)	1,342 persons (First class: 132, Economy class: 1,210) (1等) (2等)	375 persons (First class: 135, Economy class: 240) (1等) (2等)	HIKARI: 1,342 persons KODAMA: 1,483 persons
(3) Number of trains per day (一日の列車本数)	255 trains	About 25 trains	
2. Transport efficiency (輸送の効率)			
(1) Energy consumption per passenger (一人一キロの消費エネルギー)	9.9kW	16.4kW	
(2) Car manufacturing cost per passenger (一人一キロの車両製造費)	¥ 2.13 million (百万円)	¥ 5.07 million (百万円)	
3. Passenger service (客室サービス)			
(1) Car body cross section ratio (車体断面比)	1	0.7	○ Shinkansen cars are equipped with air cushion. (新幹線は空気バネ台車)
(2) Flexibility to number of passengers (乗車弾力)	Can exceed seating capacity (定員を超えても乗車可能)	Restricted to the seat limit. (定員しか乗車出来ない)	
(3) Seat interval (座席間隔)	98 cm	84 cm	○ Seat interval in the Jumbo planes are about 90 cm. (ジャンボ機は約90cm)
(4) Air sealing (気シール)	No discomfort to passengers' ears at tunnel entrance and exit. (トンネル出入口でも客室には耳の圧迫感がない)	Not structured with air sealing. (気密構造となっていない)	
4. Situation along the railroad (沿線の状況)			
(1) Topography (地形)	Mountains along the road. (起伏に富む山岳地帯)	Plain of gentle slopes. (なだらかな平野)	
(2) Population distribution (人口分布)	Densely populated area. (沿線は人口稠密である)	Mostly pastureland (牧草地が多い)	
5. Operating results of 17 years (17年の実績)			
(1) No accident (17年間無事故運転)	Number of transported passengers in 17 years: 1.7 billion (persons). (17年の総輸送人員)		
	Total kilometerage of operation in 17 years: 550,000,000 km (17年間の走行距離) (Equivalent to 716 round-trips to the moon) (月まで716往復)		
(2) Experience and improvement (17年間の経験と改良)	Improvement of coaches and facilities Implementation of countermeasures against snow, rain and wind (車両の改良, 雪, 雨, 風の対策の実施)		

Organization of Ministry of Transport



Rail Maintenance System Flowchart

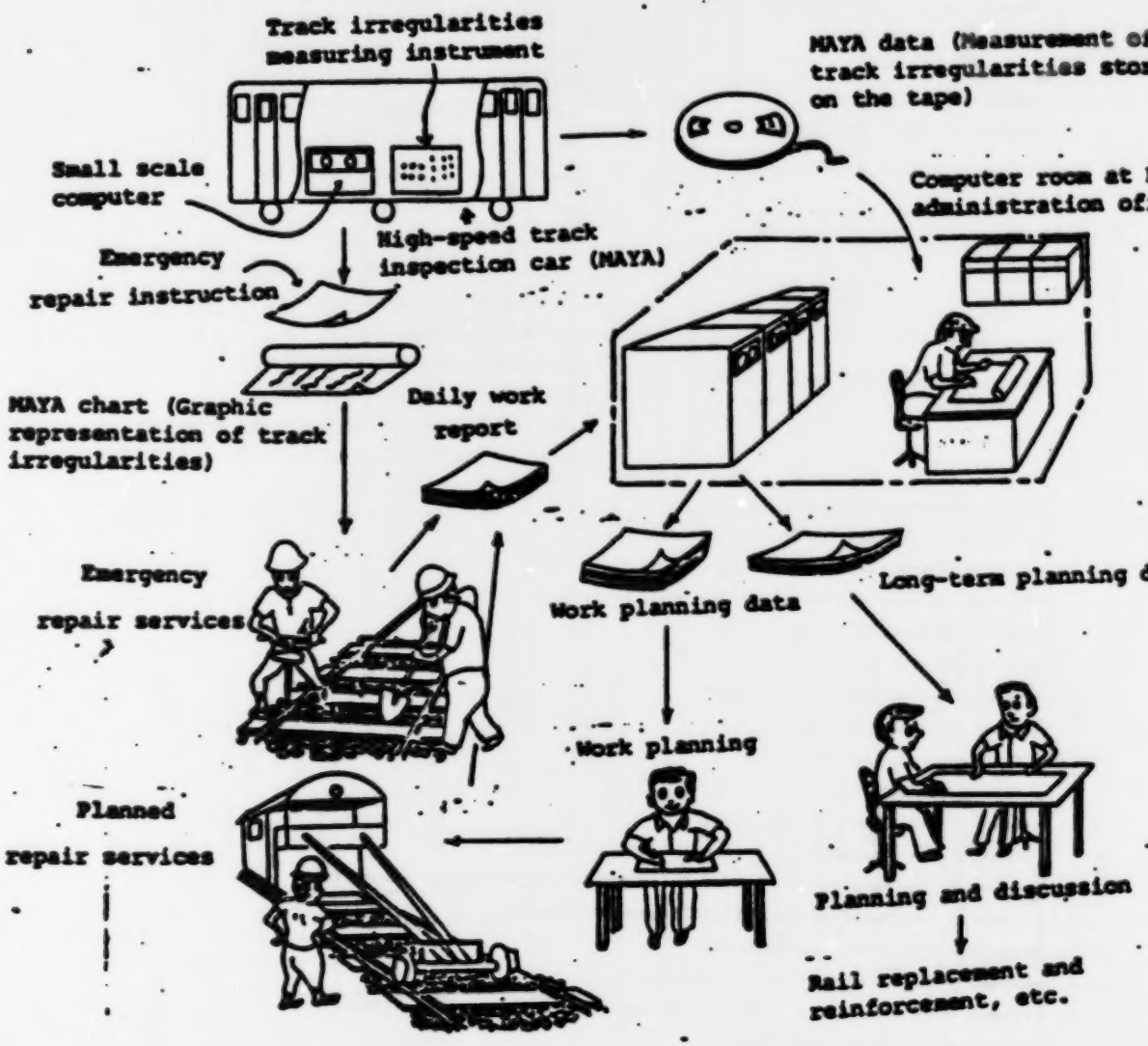

Track irregularities measuring instrument
MAYA data (Measurement of track irregularities stored on the tape)
Small scale computer
Computer room at Railway administration offices, etc.
High-speed track inspection car (MAYA)
Emergency repair instruction
MAYA chart (Graphic representation of track irregularities)
Daily work report
Emergency repair services
Work planning data
Long-term planning data
Work planning
Planned repair services
Planning and discussion
Rail replacement and reinforcement, etc.

Fig 1

Latest Automated Marshalling Yards

I Outlook of new facilities

Michito TANAKA
Chief,
1st Station Yard Div.,
Construction Dept.,
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Since the completion of the Koriyama Marshalling Yard in 1968, the automation of freightyards in the JNR has been pushed vigorously. The Takasaki Yard was completed in 1970, the Shiohama Yard and the Musashino Yard in 1974, and now the Kitakami Yard and the Suotonda Yard were completed in October 1978.

The automation of JNR yards is achieved by a general system comprised of the automation of the three subsystems: The freight car control system for automatic control of freight cars rolling down the hump into the directional sorting tracks; the route control system for automatic control of route-setting in shunting of freight cars in the yard; and the information processing system for control of general information in the yard.

In the JNR there are two types of automated yards. One is partially automated yard where only the freight car control is automated and the other is fully-automated ones where all the three systems of freight car control, route control and information processing are automated.

Automatic control of rolling freight cars is divided into the control of cars at the hump end leading to the sorting tracks, and their control on the sorting tracks.

At the hump end, in every JNR automated yard, pneumatic car-retarders are installed in one or two steps, by means of which the speeds of rolling cars are adjusted by a combination of electronic equipment and computer. On the sorting tracks, unlike at the hump end, several systems of car speed control using various devices are available: the target-shooting system for intermittent control, the Dowty system and the linear motor car system for continuous control.

In the target-shooting system the multi-stage car-retarders installed on the sorting tracks are controlled by a computer to regulate the speeds of rolling cars. The Koriyama Yard and the Musashino Yard work on this system.

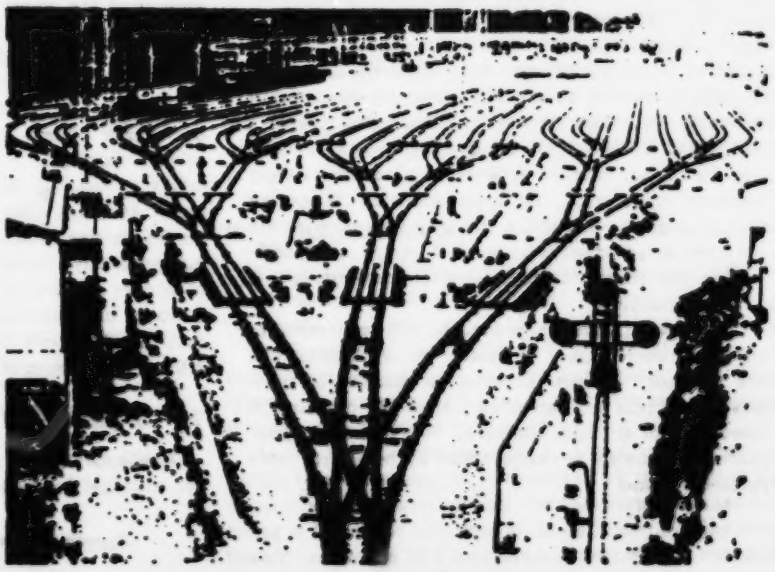
This system has been the most popular one; but having some problems on intermittent control itself, it has not been adopted for the recent automated yards which prefer the continuous control.

In the Dowty system the rolling cars are kept to a constant speed of 5 km/h by a series of oil-pressure cylinders installed at 2~3 m intervals inside of the sorting track. The Takasaki Yard works on this system. The control devices employed in this system are extensively simplified as compared with the ones in the other systems. Thus the system is highly suitable for continuous control of slow-running freight cars but its adoption is not recommended in residential zones where the noise produced would be public nuisance.

The linear motor car system is used for continuous control by which the rolling cars are arrested by a linear motor car operated on the sorting tracks; the Shiohama Yard, the Kitakami Yard and the Suotonda Yard are working on this system. The linear motor car is a highly sophisticated device which may be called a perfect one for continuous control, but its advantage are offset by high cost and incompatibility with makeup operation.

At the Suotonda Yard the hump end is equipped with car retarders and screw boosters. The Suotonda Yard has been designed as a medium-scale one, and it is the first one on which hump has been reduced in height and devices for acceleration and deceleration are introduced at the hump end.

The easy-to-roll cars are decelerated by car retarder and the hard-to-roll ones are accelerated by screw booster. Thus they can be given an adequate speed before being delivered



View of the Kitakami Marshalling Yard

results, this system has been practically adopted since October, 1978. It will be useful in effectively automating a yard with a low hump, and its performance results are being watched with great expectations.

A fully-automated yard is one where the route-setting is automated for shunt engines in the yard, and for arriving and departing trains, in addition to the freight car control. Moreover, the automation extends even to the formulation and delivery of operation plan for breakdown, makeup, and relay etc. and to the preparation of a breakdown list from the information on the cars present within the yard and the taking of statistics. The Musashino Yard and the newly completed Kitakami Yard now work on this system.

The Kitakami Yard is the latest fully automated JNR yard, one of its outstanding features being in automation of sorting tracks by stations. In an ordinary yard the shunt engine kicks off the cars to be sorted, but at the Kitakami Yard the sorting is done with a combination of screw-

Meanwhile the sorting track by stations is equipped with car retarders and Dowty devices for speed regulation of kicked cars. This will provide an important key to yard modernization of the JNR because it can automate small-scale yardwork at freight stations.

Following the successful development of yardwork automation by the combination of screw boosters and car pushers, the JNR continues to develop or improve yard equipment and systems for promotion of yard automation.

The JNR has successfully realized automation in planning the construction of new yards up to this time. Now it is faced with the necessity of automating the yards already in operation. But in these cases, in contrast to the construction of a new yard, we must develop an improved system of automation and the method of installing it without disturbing the yardwork. Thus in the near future the old yards will be modernized one after another.

II New freight car speed control devices

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The linear motor devices and new oil-pressure devices to be introduced for speed control of freight cars at the Kitakami Yard and the Suotonda Yard recently completed are described in this article.

1. Linear motor accelerator-decelerator

Four years have passed since the introduction of a linear motorized acceleration-deceleration system at the Shiohama Yard in the suburbs of Tokyo and this yard has won a favorable reputation as "a quiet yard" from an environmental standpoint. The systems employed there are those improved on the basis of ample experience in service, but they are fundamentally little modified. Trains of slim type composed of five units with car-catching rollers, air brakes, motor coils, a control device, etc. travel on an exclusive reaction-plate path laid between rails, so that a strong propulsion and braking force are developed with full play given to the nonadhesive drive. When an on-coming freight car wheelset is detected, the train starts up. When the wheelset is caught by the roller, the train runs carrying the cars with the speed adjusted to about 13 km/h to a specified position and then releases them after decelerating to a speed for safe coupling.

At the Kitakami Yard, snow-ploughs will be attached to the trains to remove snow in winter. During snowfall the running resistance of cars increases on account of snow deposits on the rails and this poses one of the problems in the speed control at automatic yards. This system designed for continuous control is characterized by being free from obstruction by snow.

At the Suotonda Yard a new roller mechanism which can capture the cars well even on curves has been partly introduced.

2. Screw booster

The new oil-pressure control devices include the screw boosters (SB) and the car pushers (CP), which have been developed in the last 5 to 6 years utilizing oil pressure for the control of freight car speed.

SB represents a slender drum with fins symmetrically attached in a 180° stagger, its screw rotation causing a squeeze of the wheel flange. The drum is driven by an oil-pressure motor and upon detection of wheels it rotates 180°. SBs are laid right and left along the rails in the track. When not working, the device can be mechanically depressed so as not to stand in the way of a passing vehicle. The device is at present used for two purposes: to keep a group of cars moving at a constant speed as low as 1 km/h, for which an engine is not effective, and to set the car speed at about 10 km/h over a specified spot. Of course it can be set for varying speeds. Each unit in the device can function independently. Therefore even if some of the units are out of use on account of maintenance or failure, the device as a whole can continue functioning little affected thereby. Sets of right and left pairs can be easily provided in arbitrary quantities even over a short distance of switches.

3. Car pusher

In the car pusher, just as in the linear motor device, the car is caught by rollers for acceleration or deceleration by

means of an oil-pressure driven pinion and a rack in the pit. Upon detection of wheels, CP measures the car speed. If the speed is below the specified range, acceleration is made; if it is above the specified range, deceleration is made. And if the speed is appropriate, CP remains inactive to let the car pass on. For the purpose of sudden acceleration or deceleration over a very short distance, a large-size oil-pressure motor is provided, but the pump installed is a small, economical one, because the necessary oil pressure only has to be built up in time for arrival of a car at CP.

These new devices are expected to play the same big role in future yard automation as the linear motor system.

III System and computer

Nobukazu INADA
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In the last 10 years the JNR has completed 6 automated marshalling yards. There are still a number of nonautomated yards and for the purpose of introducing automation system in these yards economically and efficiently the JNR has decided upon reviewing and restructuring the existing systems, and promoting systems standardization. In line with this policy, the first yard automated by the application of a standardized system has come into being at Suotonda Yard, in October 1978.

1. Background

In order to extend the automatic system to all the yards of JNR, the first thing to be done is development of low-cost yard equipment and the next is to decrease the manpower and time for the systems development. It is particularly important to prepare the software and test it on a limited number of personnel in a limited period. It is from this standpoint that the JNR has made the decision to embark on systems standardization.

2. Car control system

The yard automation system is composed of the control system and the information system. The control system is divided into the car control system for use in the sorting operation and the route control system dealing with the yard operations other than the sorting. The basic idea is to standardize all of these three subsystems, but first comes the standardization of the car control system which calls for the most urgent attention.

3. Speed control system

The heart of the car control system lies in the speed control of cars moving on the sorting track. Conventionally there are the following three systems available: the target-shooting system, the oil-pressure unit system, and the linear motor system. Standardization covers all types of yard equipment to be used, their combination, and computer interface in each of these systems.

4. Computer program

The functional requirement of car control system differs little from yard to yard. With this in mind, efforts have been made to substantially cut down the necessary manpower for the programming involved in yard automation by developing a program commonly available to all yards.

The standardized program possesses the following features:

(1) The program can be constituted independently of the track layout (number of sorting tracks and number of devices).

(2) Necessary programs can be selected out of a group of packaged programs to combine them to meet the system function. Thus the program is adaptable to different control systems.

(3) In principle the real-time control program is made core resident. Accordingly the control can continue in the event of the failure in peripheral devices such as the magnetic disk, etc.

5. Introduction at Suotonda Marshalling Yard

The standardized car control system is employed for its first application in the automation of the Suotonda Yard. Owing to some modifications in the systems of control and operation a new package has been formulated for about 6 % of all the programs (46 K steps).

As initially estimated, the total manhours for this yard automation over the entire period from systems planning to inauguration will be reduced to about 1/2 of those required in past automation.

6. Future prospects

Standardization of the other two subsystems, i.e., the route control system and the information system is now in progress.

Work on the route control system is attempting to achieve implementation of an inexpensive, easy-to-use system by reviewing the modes of operation and promoting the microcomputerization of interlocking devices.

As for the information system, it is desirable from its nature that the system be extended to all the yards in the country with in a short period. For this purpose manpower-saving is the major task, and an all-out effort is being made toward realization of a standardized system with minimum functions including ACI (Automatic Car Identification).

The development of technology, in a sense, brings about great diversification. Should this be allowed to happen without coordinating it, the operation of inspection, repair and maintenance would become inefficient and uneconomical. To achieve a balance, there arises the problem of standardization. Introduced in this issue is our response to part of this problem.

It is of prime importance not only to construct a railway but to operate it with efficiency. It is essential that mass means of transport such as the JNR, be operated in a systematic way. This is no less important than the development of technology, and is one of the distinctive features of JNR. Also highlighted in this issue is our attempt to achieve efficient operation in every field.

Le développement de la technologie fera naître une grande diversité de techniques. Mai si la technologie était laissée telle quelle, les opérations d'inspection et d'entretien deviendraient inefficaces et coûteuses. Le problème de la standardisation se pose. Nous présentons ici, un aspect de la situation actuelle. L'essentiel n'est pas seulement de construire une voie mais d'en assurer aussi la gestion. Il est indispensable de mettre au point un système de gestion quand il s'agit de moyens de transport de masse tels que ceux des J.N.R. Ceci n'est pas moins important que le développement de la technologie et les J.N.R. se distinguent d'une façon remarquable dans ces deux domaines.

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MUSASHINO MARSHALING YARD

1976

JAPANESE NATIONAL RAILWAYS

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1. FOREWORD

It is to be pointed owt that in and around Tokyo within the Metropolitan Area, the reclamation of the industrial complexes on the Tokyo Bay and along the inland, as well as the rapid urban development, etc., has become the order of the day. As natural consequences, the remarkable growth of the freight volume has been brought about and the structure of the rail freight transportation is also undergoing substantial changes.

Under these circumstances, the Musashino Marshalling Yard has been borne, as a step-forward of the improvement plan of the freight traffic within the Metropolitan Area. It so happened in October 1974.

In constructing the Musashino Marshalling Yard, it has been designed to introduce positively the newly developed techniques and systems, thereby establishing the coordination of man and machine, together with the consolidation of technology and intellect of the Japanese National Railways. In this way, the automated yard of the world's latest consumation has specially been aimed.

The relevant layout of this Marshalling Yard is as shown in Fig. -1.

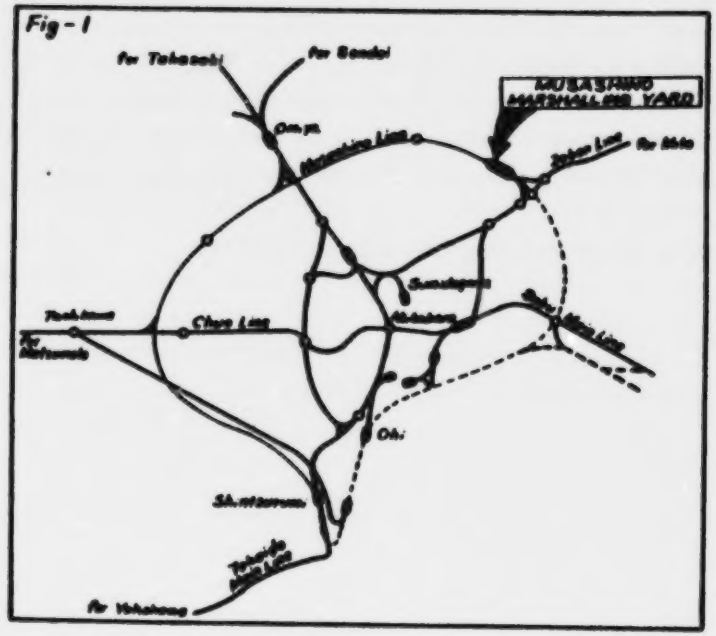


Fig - 1
For Takasaki
For Sendai
MUSASHINO MARSHALLING YARD
Chuo Line
For Ome
For Mito
Chuo Line
For Yokohama

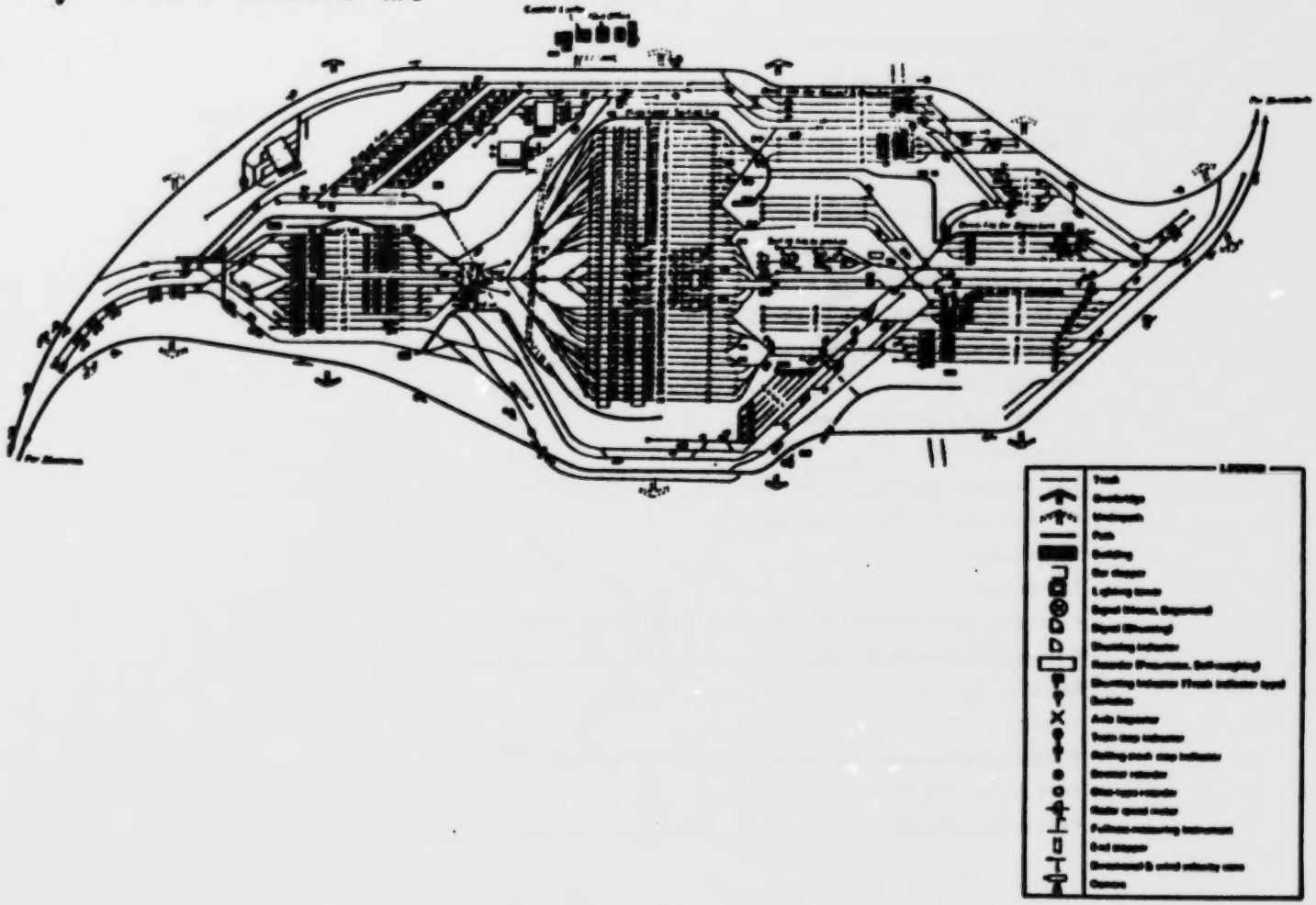
2. Outline of Facilities

The track layout and the outline of the related facilities are as shown in Fig. -2.

Main features are shown hereunder:

Total expanse	1,050,000 m^2
Maximum length	5,200 m
Maximum width	360 m
Number of cars decomposed	about 4,400 cars/day
Investment amount	about 28,000 mil. yen
Directional classification track	30
D-shaped arrow feather track	9
S-shaped arrow feathered track	5
Arrival track	13
Arrival and departure track	7
Departure track	13
Car retarder (pneumatic type)	48
Car retarder (self-weighing type)	41
End stopper	41
Car stopper	15
Car retarder (hydraulically-operated speed-diminishing type)	1,219
Car retarder (hydraulically-operated speed-accelerating type)	700
Signal	264
Switch	494
Measuring equipment for uneven loading	2
Data processing computor	1
Controlling computor	1

Fig. 2 MUSASHINO MARSHALING YARD



3. Characteristics of Planning for Facilities

The Musashino Marshalling Yard is so designed as to attain high efficiency and safety in yard operations. For this purpose, the introduction of various means have positively been made as mentioned hereunder.

(1) Automatic System

The automation of this yard is maintained, based on the following three fundamentals.

(1)-1 Fixation of yard operation

The yard plays an important part as the mainstay for shunting the freight cars in traffic activities. Various yard operations relative to these kinds of work (e. g., traffic adjustment, car distribution planning, information collecting, statistics processing, co-ordination among the relevant organizations, field work, etc.) largely depend on human vigilance and labor, entailing necessarily a great labor-intensive propensity under the current conditions.

The Musashino Marshalling Yard aims to realize, as far as possible, automation or mechanization of the hitherto complicated work, based on the new freight traffic system. This represent a complete break with an old tradition of the labor-intensive working condition, ushering in a new era of the well-disposed equipment industry.

(1)-2 Improvement in efficiency of yard operations

In the conventional yard, the available information on the freight car movements, the work progress and the prospective situations, etc. is limited and cannot be fully secured timely and precisely. In addition, the field work (for train formation, train decomposition, etc.) is based mainly on the experiences, entailing unnecessary loss of time for liaison purposes and the limitations to the efficient work performance.

Whereas in Musashino Marshalling Yard, the new technique and the new system are positively developed and introduced. The unified information over the entire area of the yard is made available, thereby attaining the efficient execution of the operation planning and liaison business. On the whole, the great strides have been made in the overall efficiency of the yard operations.

(1)-3 Simplification of the yard operations

In order to make innovations in the Musashino Marshalling Yard, the complex and minute operations prevalent hitherto in the traditional yards are not appropriate to be automated as they are. Systems relative thereto would become unreasonably complicated, involving an unnecessary reform on a large scale. If left uncared-for, the effect of the new installation of this yard would be doomed to suffer an eclipse, with little prospect for satisfactory results.

Under these circumstances, the automated yard appropriate to the modern freight transport system has been established. This has been enabled by making sweeping survey over the entire scheme of field work, thereby simplifying as far as possible the relevant transport planning, freight car distribution practice, yard operations, etc.

What constitutes the new departure from the traditional yards is that the degeration of the efficiency, which is of frequent occurrence at the time of the traffic congestion has been eliminated, and the stabilized functions of the yard go on smoothly.

In order to attain the foregoing objectives, the following steps are taken:

(a) The precise grasp of the yard operations (the prompt transmission of the necessary information)

(b) The freight car distribution planning and the automation of the yard operations planning

(c) Automation of processing the train consist report, issuing the freight car coupling and uncoupling notice, and processing the statistics of freight situation report

(d) Automation of controlling the freight car movements

(e) Automation of routing the classified freight cars (a), (b) and (c) above are schematically given in Fig. -3. While, (d) and (e) above are in Fig. -4 and Fig. -5, respectively.

These are the main items which are dealt with, for the remarkable increase in productivity and the improvement in working conditions.

(2) Yard Wireless Equipment (with Starting Push-buttons)

This Yard has introduced the yard wireless system which is equipped with the starting push-buttons. The end in view is to realize the increase in work efficiency and to establish the safe operations. This is used for notification of shunting signals and other liaison purposes together with the formation of directional routes by means of built-in facilities.

(3) "One-Plateau" Hump Yard

Apart from the traditional way which is classified into the upgrade and downgrade schemes, the Musashino Marshalling Yard is of "one-plateau" high speed type. This is very conducive to the improvement of work efficiency. (The hump gradient --- maximum 87 °/oo)

(4) D-type Arrow Feathered Track

This marshalling yard constitutes the trunkyard which aims to expedite the transit of the expresses between regions. For this purpose, the relay time of freight cars is to be shortened, thereby improving the operation efficiency. Under

these circumstances, the newly-developed D-type arrow feathered tracks are installed among the directional classification tracks.

(5) Zebra Track Layout

The Zebra Track is in use to rationalize the shunting operations of locomotives onto the storage track of the engine shed.

(6) Control System for Locomotive Storage Track

Between the traffic center and the duty room of the engine shed, the indicator board is installed, so that the pooling situation of the locomotive storage may be controlled, thereby improving the operations efficiency of the locomotives.

BRIEF SKETCH OF DATA PROCESSING

Fig – 3

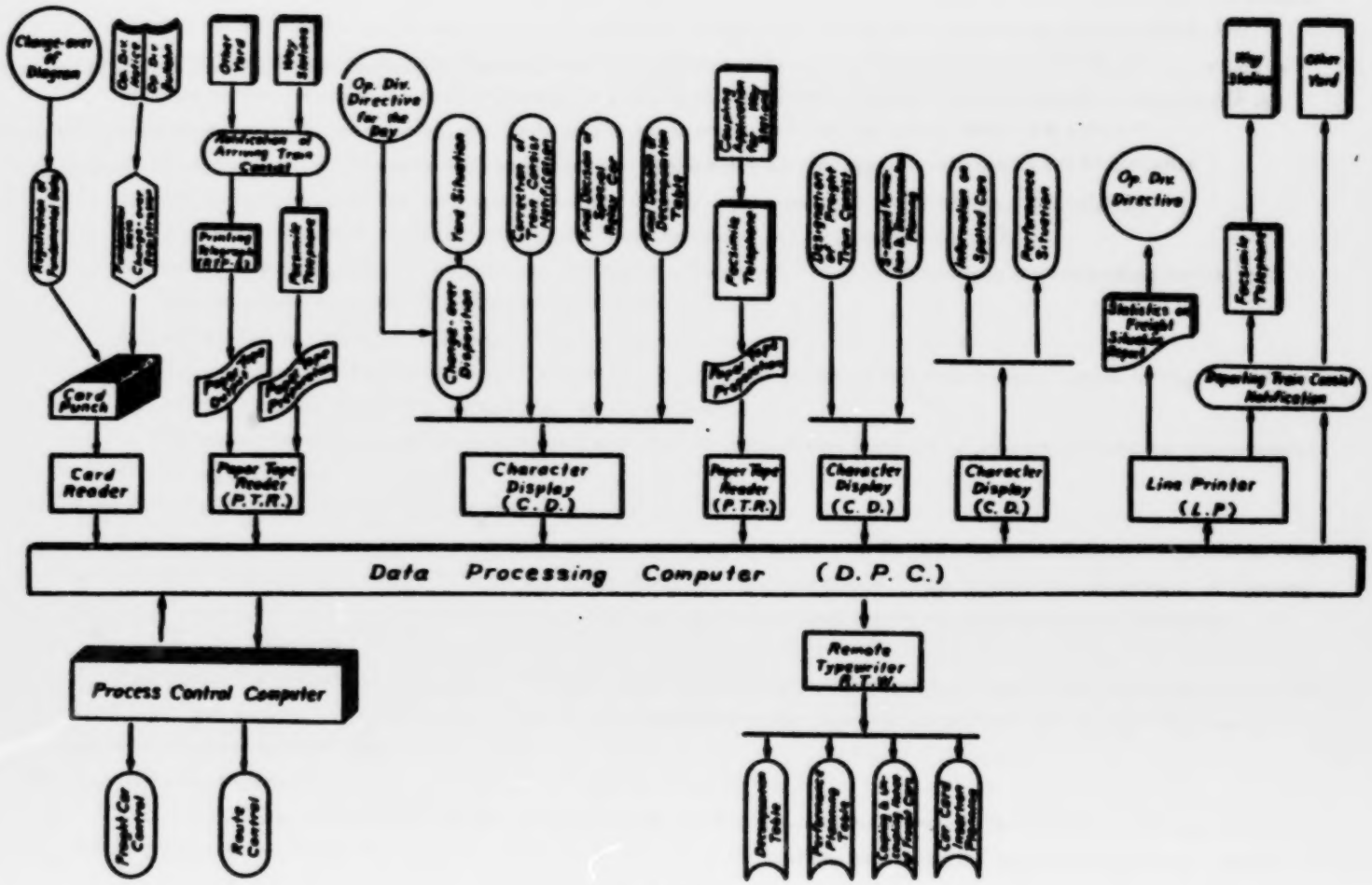


Fig.–4

BRIEF SKETCH ON AUTOMATION SYSTEM OF FREIGHT CAR DECOMPOSITION OPERATION

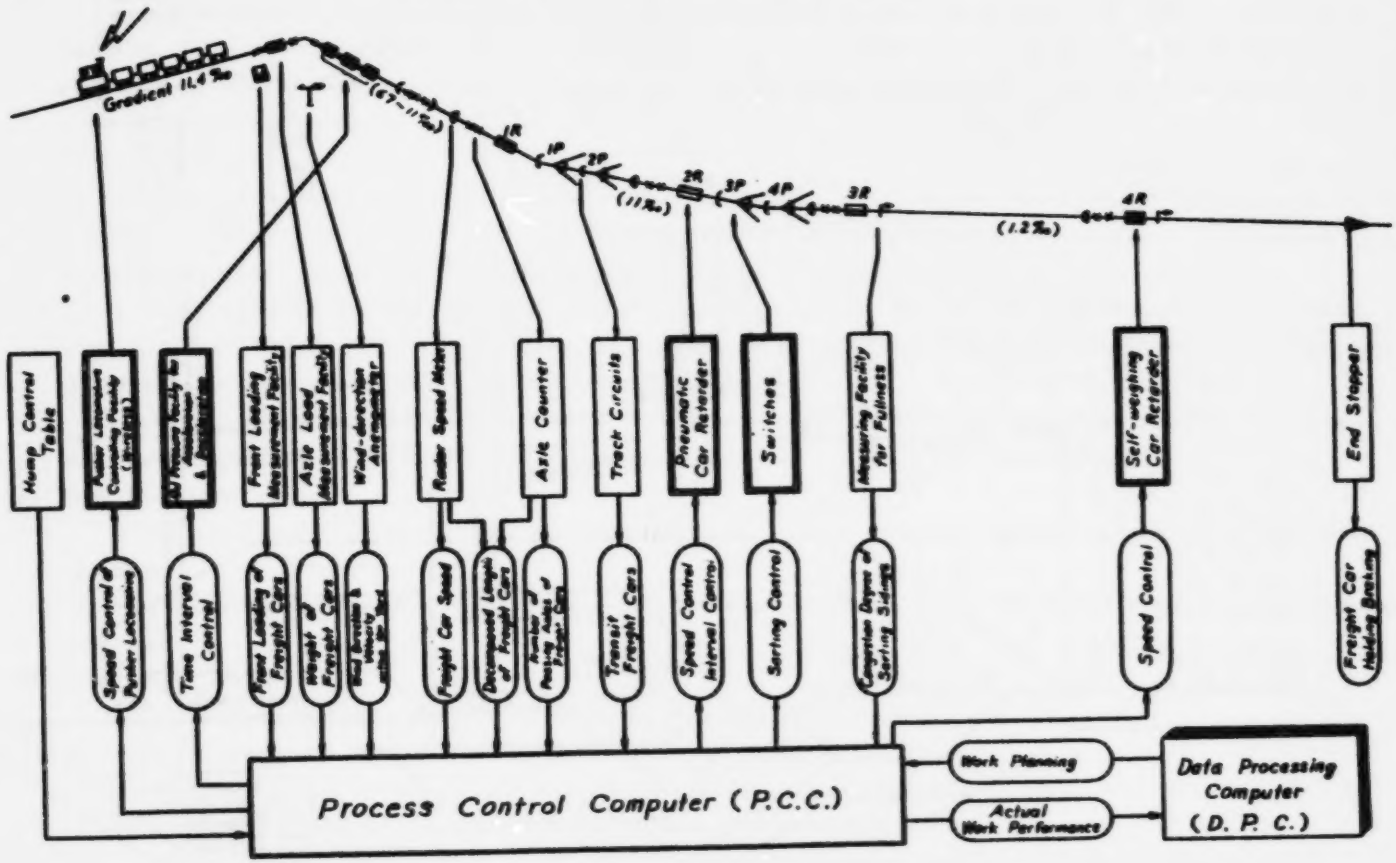
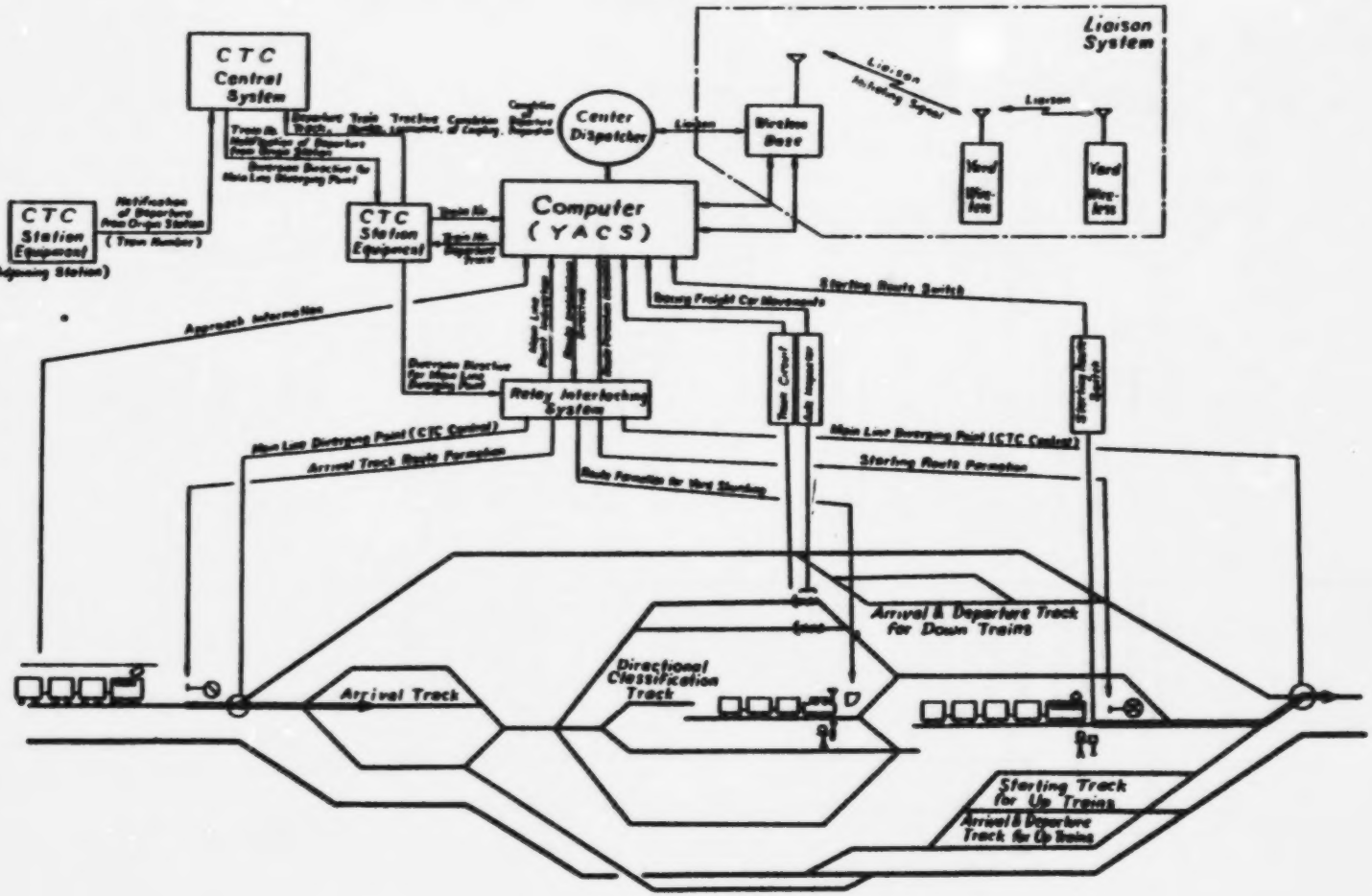


Fig.-5 BRIEF SKETCH OF ROUTE CONTROL SYSTEM



4. Performance Flow in the Musashino Marshalling Yard

(1) Performance Planning

In traditional yards, all the performance plans, including arrival, decomposition, departure, etc., are worked out manually. Here in this yard a new departure is taken therefrom, either of its own accord or through dialogues between staff members and the computers, thereby enabling the decision of each related performance with the automatic display of the performance schedule.

(2) Arrival of Trains

The approaching trains towards the yard enter the arrival track of their own accord by means of the train numbers. In cases where the prescribed tracks are blocked, change-over to the others are automatically made.

(3) Train Decomposition

In traditional yards, decomposition operations are effected by means of the decomposition table, which is manually filled out. In the Musashino Yard, the relevant documentation is worked out automatically. The directions of freight cars are likewise formed automatically in accord with the decomposition table.

In addition, the speed of the pusher locomotives are automatically regulated by means of the computer, so that each decomposed freight car may be kept at the optimum interval.

(4) Train Formation

In traditional yards, operations relative to the freight train consists, shunting methods, etc. are worked out in each outbuilding.

Whereas in this yard, the operations planning table is worked out automatically, thereby forming the relevant shunting directions.

(5) Departure of Trains

The starting routes are formed automatically just prior to the train departure time.

(6) Processing of Freight car Data

The computers of YACS automatically deals with the following items relative to the freight car data.

(a) Registration of freight car data and control of the spotted cars within the yard

All the relevant items, such as car description, car number, origin, destination, loaded article, conversion tonnage, etc., are automatically registered in the computers, thereby controlling the location within the yard in

accord with the movements by the time the related trains start.

(b) Indication of the freight car data

All the freight car data within the yard (such as car description, car number, origin, destination, etc.) can be indicated as the necessity arises.

(c) Prediction of the freight car data (when the classification tracks are filled to capacity with freight cars)

The number of cars within the yard car be enumerated, and the relevant alarm is dispatched when the tracks within the yard are predicted to be filled with cars to capacity.

(d) Preparation of freightcar data

Notice of Departing Train Consists, Notice of Train Formation & Decomposition, Notice of Freight Situations & other Statistics are prepared automatically. The said Notice of Departing Train Consists can be despatched automatically to the relevant major yards.

(e) Grasp of the operating situations

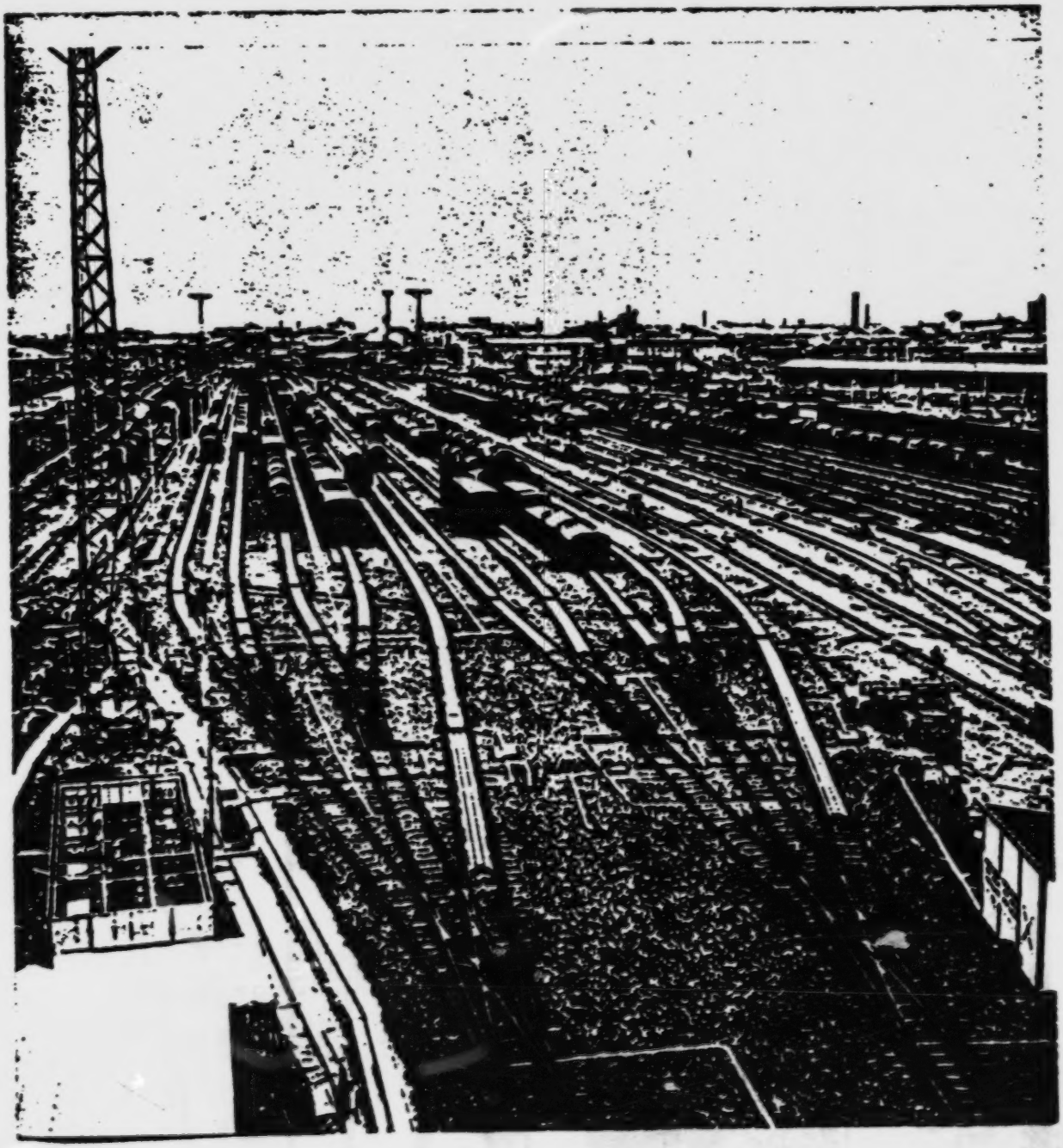
The operating situations such as arrival, formation and decomposition car be indicated upon their completion of each work unit, whenever the necessary occasion arises.

SHIOHAMA YARD

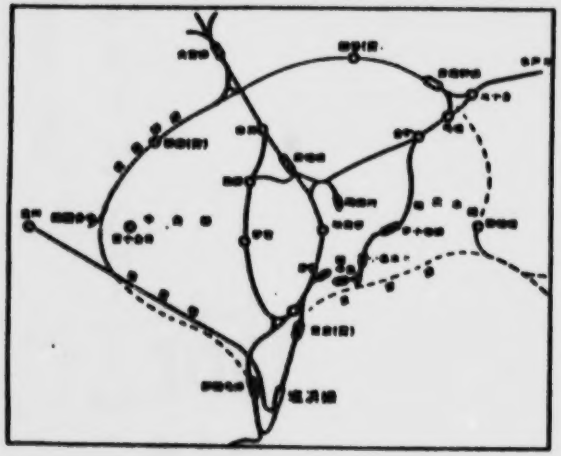
APPENDIX 7,5

リニアモータカー・コンピューター導入でヤード作業の近代化

塩浜操駅

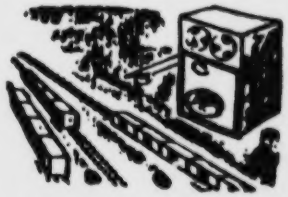


地下鉄の近代化と能力の増強を行なって行き方化と安全の安全を一段と向上させました。



●主な自動化

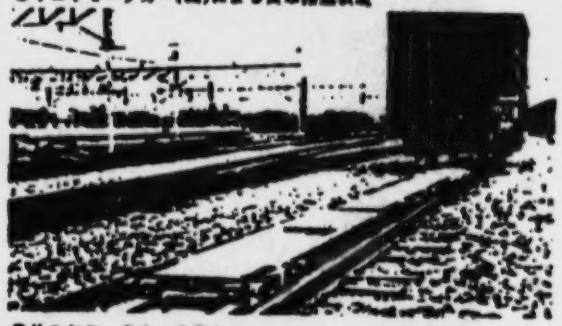
地上運転	列車間隔	列車間隔自動による3:2のデルタダーで制御
	自動運転	リニアモータカーによる加速度制御
速度制御		コンピューター制御による速度自動制御
分析組成		コンピューターによる自動化



●リニアモータの原理

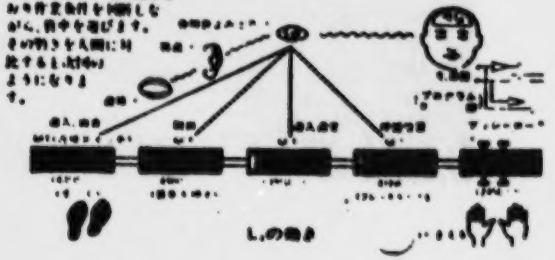
リニアモータは、1895年イギリスで初めて発明されたもので、かご引き号を鋼索その他にそって運転し、主に地下鉄に利用した例です。
この上は中下に3次巻線をまき、これに3個電流を供給して移動磁界をつくり、地上に敷設した3次同期との間に推進的吸引力を発生するもので、中1.1次、地上2次方式と呼ばれます。

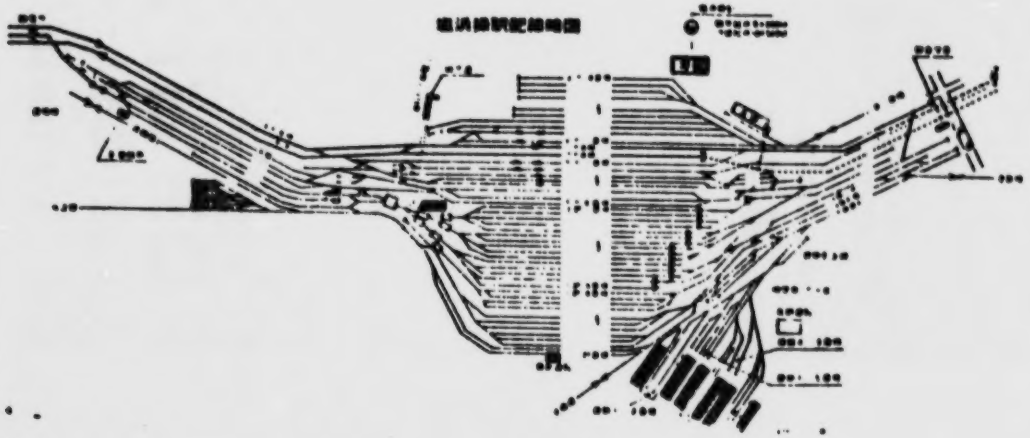
●リニアモータカー(L)による営業運転状況



●リニアモータカーの動き

リニアモータカーは自動的にコンピュータを内蔵しておき指定条件を判断しながら、自分を進びます。その例として大阪に対比すると次のようになります。



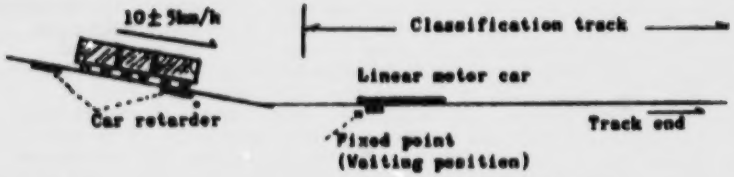


Linear Motor Car

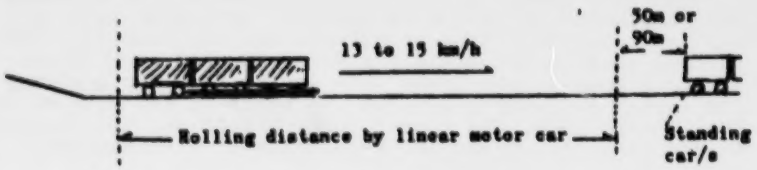
1. Function

The linear motor car is used to control the movement of freight cars on a classification track during sorting operations.

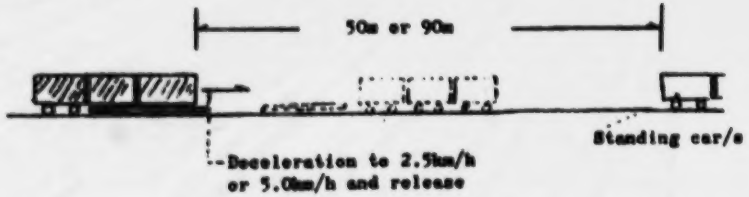
The linear motor car waits for the freight cars rolled down the hump with their speed regulated by car retarders at a fixed point near the entrance of the classification track.



The linear motor car catches as the freight cars pass over it and pushes them at a speed of 13 to 15 km/h to a point 50 or 90 meters away from the position they are to be spotted.



From the aforementioned point, the linear motor car reduces its speed to 2.5 or 5.0 km/h and releases the freight cars.



Then, the linear motor car returns to the fixed point at the entrance of the classification track to wait for the next freight cars coming in.

In the event the linear motor car meets oncoming freight cars on its way back to the fixed point, it will detect them by means of the distance approach switches equipped on the car axles. It then catches the freight cars and push them in the manner mentioned previously. This automatic operation is repeated until the classification track is filled.

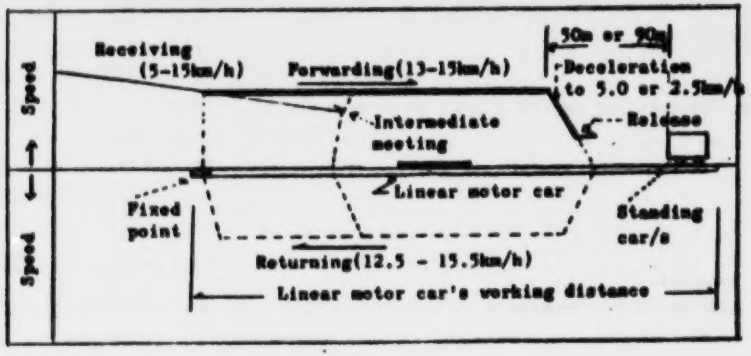
2. Operation patterns

The linear motor car operates under four patterns, as shown in the following table, based on the freight car weight and whether or not lower than normal coupling speed is necessitated.

Operation Patterns of Linear Motor Car

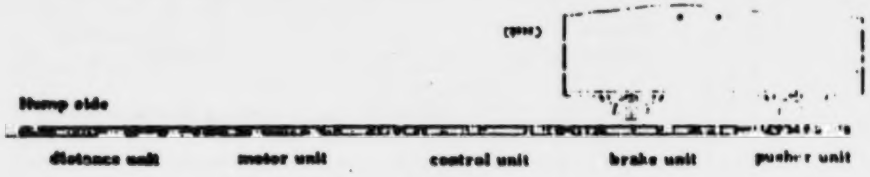
Pattern	Freight car data	Deceleration point	Releasing speed
1	Low speed coupling Under 60 tons	50m	2.5km/h
2	Low speed coupling 60 to 150 tons	90m	2.5km/h
3	Normal speed coupling Under 60 tons	50m	5.0km/h
4	Normal speed coupling 60 to 150 tons	90m	5.0km/h

3. Continuous Automatic Control Operation



4. Specifications of Linear Motor Car (LA)

a. Composition	(From hump side) distance unit + motor unit + control unit + brake unit + pusher unit
b. Weight	2,700kg
c. Dimentions	10,450mm(l) x 2000mm(h) x 880mm(w)
d. Power source ...	AC 400V 3ϕ 50Hz
e. Linear motor (primary)	Driving power: 650kg Current: 340A Synchronous speed: 25km/h
f. Reaction plate (secondary)	Al: 3mm(th) x 230mm(w) Fe: 16mm(th) x 230mm(w) coupled plate
g. Brake power	Plugging brake: 620kg Air brake: 1,200kg
h. Operation system ...	Blockless automatic operation and radio remote control
i. Freight car catching system	Relay system(variable accelerating time)
j. Freight car catching speed	Normal maximum: 15km/h Emergency maximum: 18km/h
k. Freight car rolling speed	13km/h to 15km/h
l. Freight car releasing speed	5km/h in normal coupling speed 2.5km/h in low coupling speed
m. Returning speed	12.5km/h to 15.5km/h



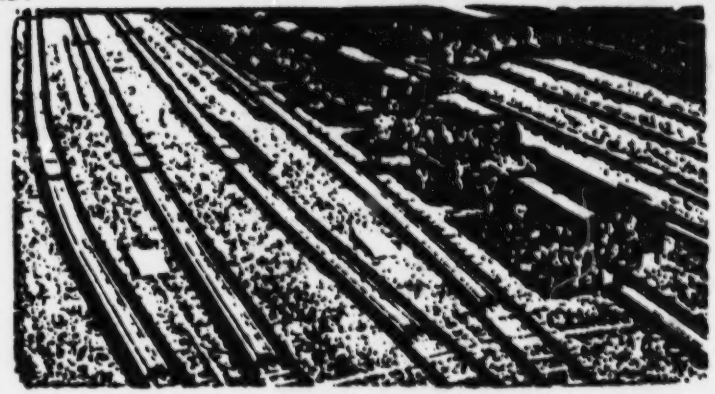
5. Principle of the Linear Motor

The linear motor itself is not new as far as the principle is concerned since it has been under study in connection with the development of the so-called maglev type of railway. It is, in brief, an ordinary rotary electric motor cut open along its axis and spread out so that the revolving motion is changed into a linear motion.

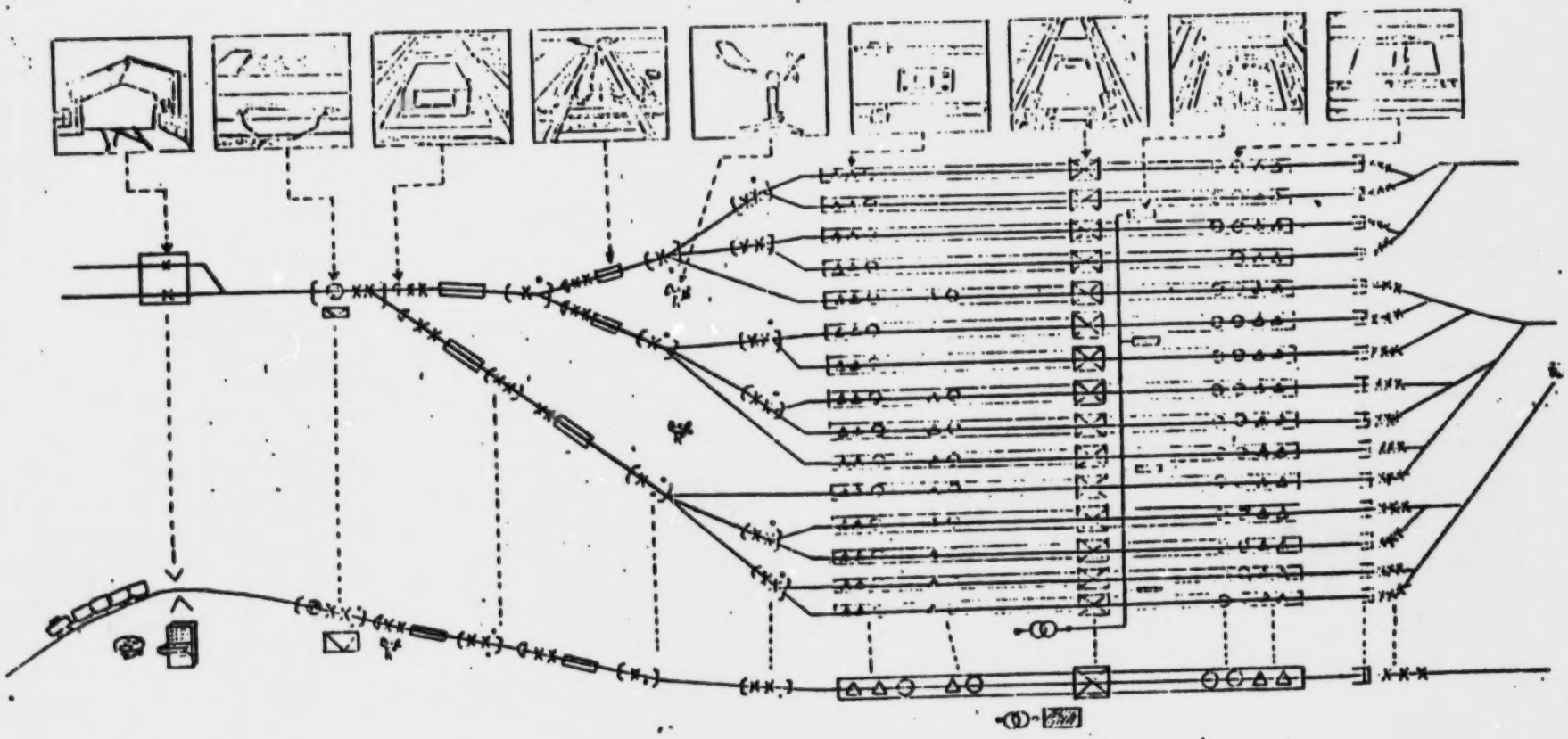
In the linear motor car used in the yard, the primary side winding is installed on the car, to which three-phase a. c. current is supplied to produce a moving magnetic field, so that linear driving force will be produced between the secondary side conductor installed on the ground. As this linear motor has no revolving parts, transmission gears and bearings, etc. are not required. It is, thus, siple in mechanism and small in size and besides, as it is not designed to be driven by adhesion between wheel and rail, it is very powerful for its light weight.

6. Role of each unit

A linear motor car is made up with five flat box-like units on small wheels, joined together. It may be likened to a robot --- the axle detector on the distance unit and other units serves as eyes; the motor unit as its feet for locomotion propulsion and deceleration; the control unit as its brain for gathering information and giving commands; the brake unit as its feet for applying the brake; and pusher unit as its hands to get hold of the freight cars. The linear motor itself may be regarded as its internal organs for conversion of electricity power.

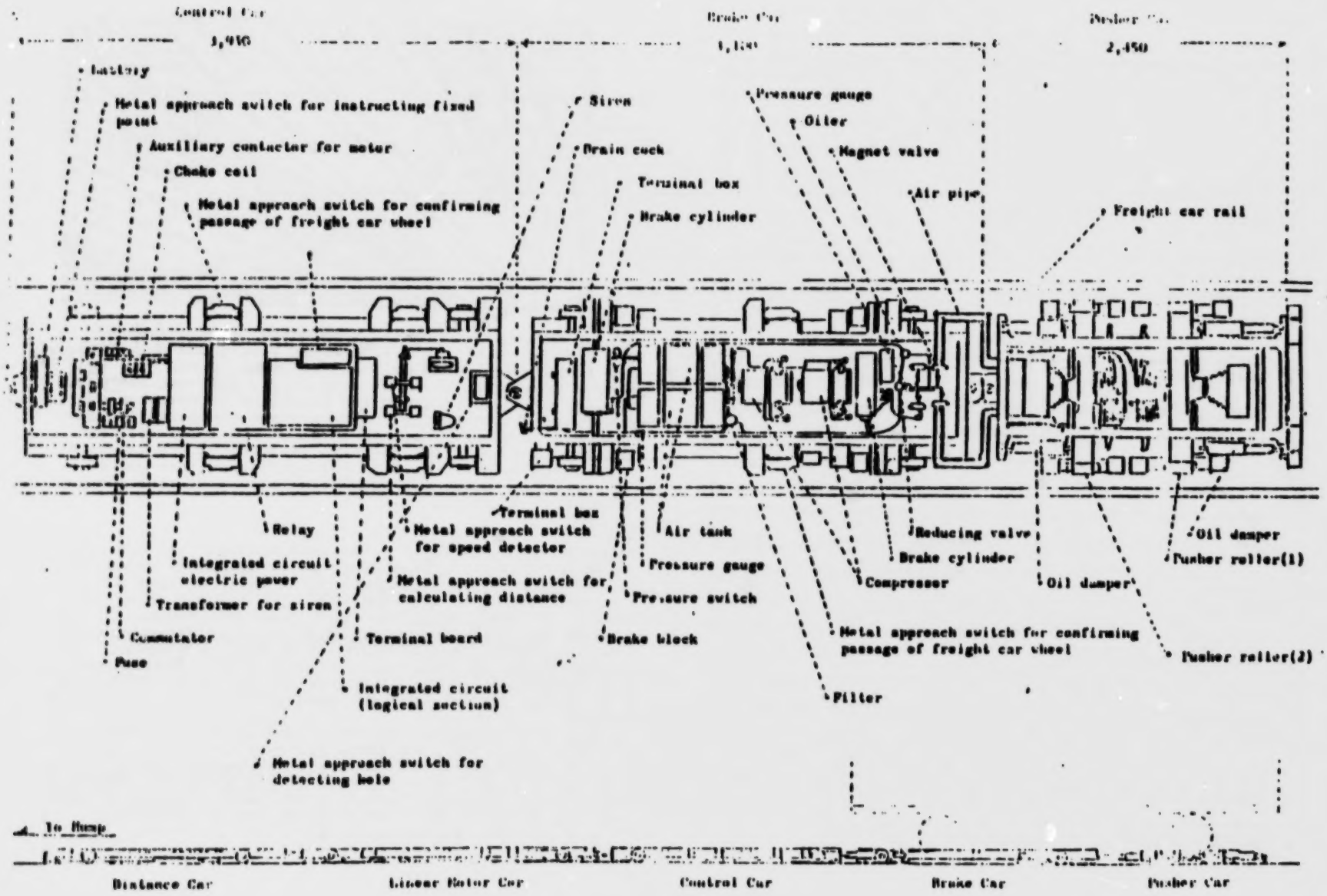


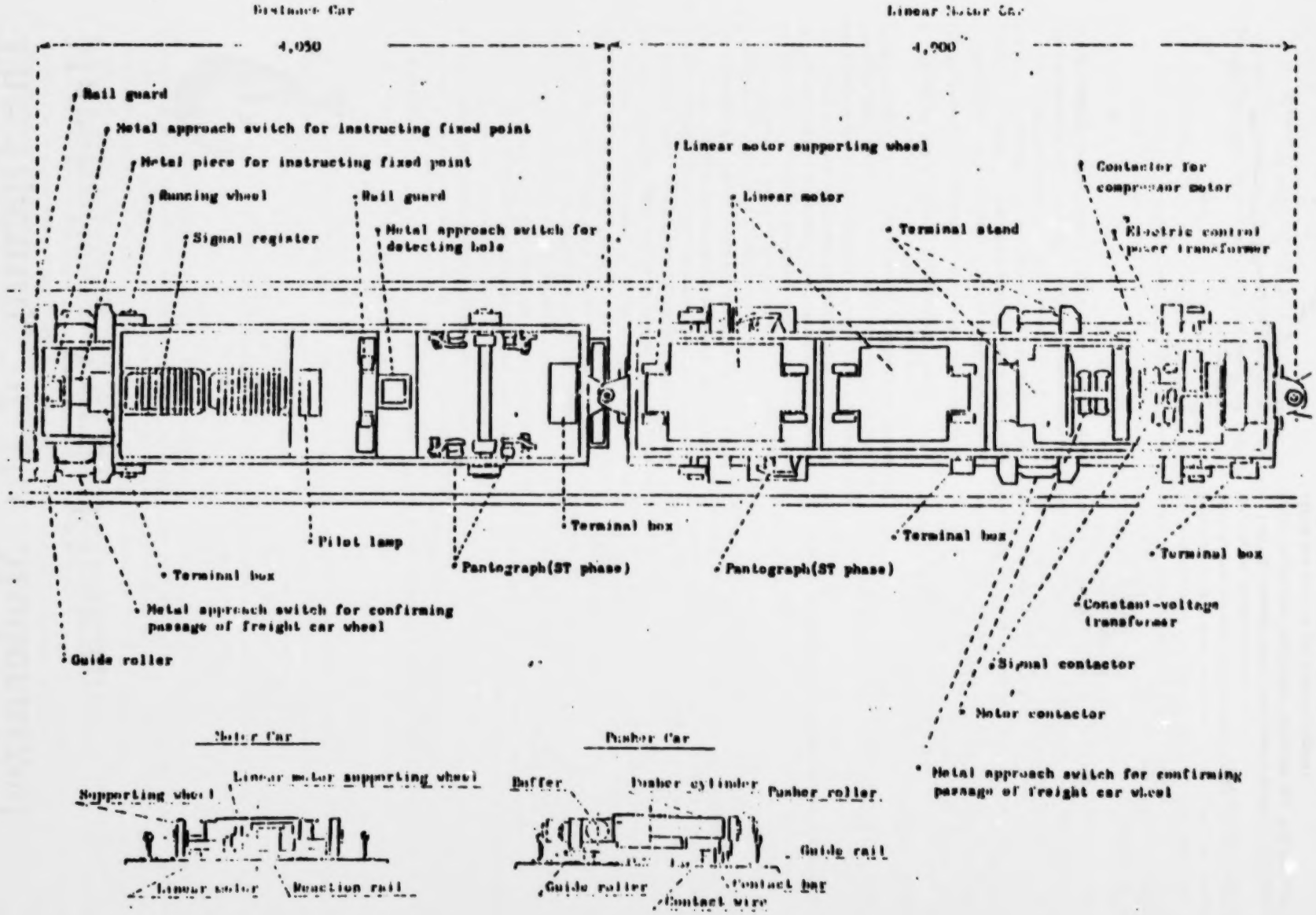
LAYOUT OF AUTOMATIC SYSTEM



Legends:

- Tape reader
- Hump control panel
- Track circuit
- Axle weighing device
- Freight car's front-end-wall measuring device
- Radar speed meter
- Axle detector
- Car retarder
- Electro-pneumatic switch
- Wind meter
- LA detector
- LA detecting hole
- Linear motor car (LA)
- Electric power source for LA
- Low-voltage control box
- End stopper


Control Car
3,950
Brake Car
1,150
Pusher Car
2,450
Battery
Metal approach switch for instructing fixed point
Auxiliary contactor for motor
Choke coil
Metal approach switch for confirming passage of freight car wheel
Siren
Drain cock
Terminal box
Brake cylinder
Pressure gauge
Oiler
Magnet valve
Air pipe
Freight car rail
Relay
Integrated circuit electric power
Transformer for siren
Commutator
Fuse
Terminal board
Integrated circuit (logical section)
Metal approach switch for detecting hole
Terminal box
Metal approach switch for speed detector
Metal approach switch for calculating distance
Air tank
Pressure gauge
Pressure switch
Brake block
Reducing valve
Brake cylinder
Compressor
Filter
Oil damper
Metal approach switch for confirming passage of freight car wheel
Oil damper
Pusher roller(1)
Pusher roller(2)
To Hump
Distance Car
Linear Motor Car
Control Car
Brake Car
Pusher Car


Distance Car
4,050
Linear Motor Car
4,900
Rail guard
Metal approach switch for instructing fixed point
Metal piece for instructing fixed point
Running wheel
Rail guard
Signal register
Metal approach switch for detecting hole
Linear motor supporting wheel
Linear motor
Terminal stand
Contactor for compressor motor
Electric control power transformer
Pilot lamp
Terminal box
Pantograph(ST phase)
Terminal box
Pantograph(ST phase)
Terminal box
Terminal box
Metal approach switch for confirming passage of freight car wheel
Guide roller
Constant-voltage transformer
Signal contactor
Motor contactor
Metal approach switch for confirming passage of freight car wheel
Motor Car
Linear motor supporting wheel
Supporting wheel
Linear motor
Junction rail
Pusher Car
Buffer
Pusher cylinder
Pusher roller
Guide rail
Guide roller
Contact bar
Contact wire

The Opening of the Modernized Marshalling Yard, Kitakami

Kazuto KUSANO
Chief,
1st Station Yard Div.,
Construction Dept.,
JNR Head Office

1. Foreword

As the Tohoku Shinkansen which is being constructed interferes with the freight facilities of the Kitakami and the Morioka Station, it became necessary to construct a new yard for their substitute. In planning the new marshalling yard it was decided to consolidate the freight services of some marshalling yards located in the surrounding district. Modernization of freight service was to be carried out in line with the corporate policy on all the aforementioned substitutional facilities. For this reason the size of the new yard was to be an aggregate containing the Ichinoseki and the Kogota Marshalling Yard in addition to the yards at Kitakami and Morioka mentioned first. That is, the design of the new yard was based on the calculations which called for the daily handling capacity of 1,700 cars and the peak capacity of 2,000 cars a day.

As a principle, the yard work would depend on automation by computer. In addition to the automated break-up and sorting of freight cars already established in JNR, route control and information processing would be automated, so the plan was meant for an integrated automation of yard. The work was completed and the services started in October 1978. Brief description of the new yard will be given below.

2. Roles of the Kitakami Marshalling Yard

(1) Distribution of marshalling yards in the Tohoku region

Distribution of marshalling yards in the Tohoku region is indicated in Fig. 1. The entrance is constituted by Nagamachi Yard and the exit, or approach to Hokkaido, is the Aomori Yard. With these two as croxes of the framework, other yards are located at nodes leading to the branch lines, and designated as local marshalling and way freight train handling yards. The crux yard holds the position of domain over those locally oriented yards of the whole region that handle the way freight trains, and put together odds of freight cars not comprising to a train at those subordinate yards, and set up a through interblock (i.e., interregional) train, or perform the work in the reverse order.

Fig. 1 [illegible]

The locally oriented marshalling yard handles mainly those trains which arrive in or start from branch lines and near by. The local car marshalling yard has to have a capacity large enough to pool and forward freight cars adjusted to suit the work time of the freight stations within its territory in charge in order to relieve them from work burden as much as practicable. However in actual fact, the marshalling yards in the Tohoku region are not fulfilling these functions because of scarcity of surplus capacity. Hence, taking advantage of the Kitakami Marshalling Yard project the rationalization of freight service in the Tohoku region with each of the yards imparted proper missions was aimed for as a necessity.

(2) Benefits expected from construction of the marshalling yard

The following improvements come from the construction of the Kitakami Marshalling Yard.

(i) Speed-up of shipment, resulting from the unification of handling of way freight trains

The establishment of the Kitakami Marshalling Yard is, in one sense, the merger of the yards at Kitakami, Morioka, Kogota and Ichinoseki, so the services for the areas rendered at each of those yards in the past are now directly controled by the Kitakami Yard. This is to realize faster shipment of freight owing to the elimination of the so-called duplicated transshipment, or the transport of freight cars by way of one marshallying yard to the next.

(ii) More straight shipments

As the concentration of yard service enables the new Kitakami Yard to take up the odd shipments hitherto scattered over the smaller yards, freight lots for a long haul are now easier to raise into a complete train and, with the automation and modernization of the yard, the complete information network enables more freight to be transported directly by through trains.

(iii) Rationalization of shipment route (Unification of trunk routes of shipments between the Pacific and the Japan Sea coast in the Tohoku region)

In the past, there were four routes established for the connection between the Pacific side and the Japan Sea side

and the routes of freight car forwarding also become entangled.

When such shipments are concentrated to the Kitakami line, which has the greatest transport capacity to make it a single route and effect an enlarged transport capacity and the other lines are closed to freight trains, the better utilization for passenger transport can be augmented.

(iv) Adjustment of the timetable of way freight trains

As stated before, the local freight car marshalling yard is commissioned to lighten the burden of the freight stations under its charge as much as possible. But, on account of the insufficiency in capacity of marshalling yards in this region, the trains have to be operated all day long, making night work a necessity for the stations linked with the local car marshalling yard. Nontheless the cargo handling work is avoided in the night, and therefore the loading and shipment are put off till the following day, much against the corporate policy of quick delivery of freight. As a solution to this dilemma, this marshalling yard at Kitakami performs the particular function of adjusting the timetable so that freight cars will arrive in the morning and start in the afternoon: a work pattern with the underlying timetable diagram designed to produce intended effect of better shipment operation.

3. Facility installation plans

(1) Track layout plan

The yard work roughly consists of train arrival→break-up →train set-up→departure. The track layout was planned to avoid the possibility of those works interfering with one another, and a straightline track layout from train arrival to the departure was worked out. In view of its mission as the master marshalling yard of the region, the layout was made to contain a set or two of herringbone trackage fit for the break-up and make-up of trains for direct traffic on one hand and of trains bound for minor stations under its wing on the other (Fig. 2).

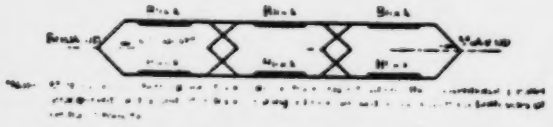


Fig. 2 Multi-succession herringbone tracks

Capacities of principal equipment were calculated by using independently respective empirical calculation formulae each being applied to the number or quantity of the objects and works handled at average level of business. But, considering the fact that different type of equipment mutually relate to one another, specially in the case of marshalling yard, such calculations made individually for each type of equipment could possibly cause an imbalance in the whole set when serving a series of correlated jobs. For this reason, the equipment installation planning for this and marshalling yard based the calculation and check-up of capacities of principal kinds of the equipment on a simulation study worked out by computer, presenting a condition as if freight cars had actually moved along in the yard.

) Planning of automation

The yard work today takes so many hands that it appears to be the so-called labor-intensive phase of the railway [illegible] and b) destination is extremely hazardous, (in order to stop the broken up and kicked-off car at the specified spot to be ready for coupling to a new train being composed, the worker waits for it rolling by the sorting trackage and, as it comes along, jumps on to it, and brakes it on his own and brings it to a halt) and this has never ceased to cause casualtys. The automation aimed to change the yard work, particularly the train break-up operation, from the labor-intensive category to the plant-industry category, to thereby make the marshalling yard a safer place of work. In the following passages the contents of automation of the Kitakami Yard will be briefed.

(i) Control of freight cars

a. Controling the speed of cars rolled down the hump towards sorting track.

(a) Design of hump grade

Distance covered by the cars rolled down, the speed curve, etc. were decided beforehand and the hump height was fixed at about 2.2 meters and the maximum grade at 50 ‰ as indicated by the conditions necessary. Such as, the speed of the cars rolled down should be 13 + 2 km/h at the entrance of sorting track and that even those ones which could not roll smoothly because of increased rolling resistance would somehow reach the beginning of the sorting track.

(b) Control of speeds between the hump and sorting track

Freight cars vary, as do their loads, and in turn, the running resistances are different. Even if the cars are rolled over the same grade, their speeds are not uniform. For this reason, if the freight cars differring in speeds are started rolling at a fixed headway, it might happen that the subsequent car overtakes the preceding car before it reaches the specified spot. To avoid this, car retarders are installed somewhere between the top of the hump and the entrance of the sorting trackage in order to adjust the rolling speeds of the cars and the interval in between will remain constant.

(c) Control of speeds within sorting track

There are two methods of controlling the rolling speeds of freight cars on sorting trackage, namely point control by the car retarder and the continual control by means of installing certain automation equipment. Each of the two has its strong points and weak points and it is hard to say which is better. But, in this particular yard, which is located in a snowy zone, the continual control system by the linear motorcar was chosen because the car retarders were thought vulnerable to snow and not very competent in keeping the car speeds contant after them. (See Figs. 3 and 4.)

(d) Control of car speeds within the herring-bone track

The linear motorcar operates on the passage tracks and the car retarders and doughty units operate on the pocket trackage. In the train set-up trackage for trains bound for the same stations, some new oil pressure equipment such as the screw booster and car pusher, are installed taking the place of shunting locomotives which were employed in the past. (See Figs. 5 and 6.)

b. Route control of freight cars rolled down (automatic throwing of switches and composition of routes)

To lead the freight cars rolled down into specified tracks, the switches laid on the way are automatically thrown by linkage with computers.

(ii) Route control

Routes for trains arriving at or starting from the yard and for shunting within the yard are automatically composed by linkage of information and computer.

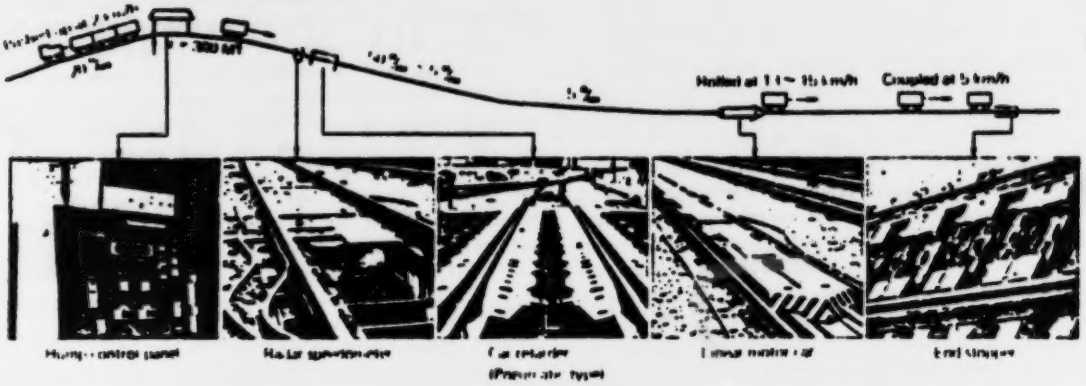


Fig. 3 Hump works

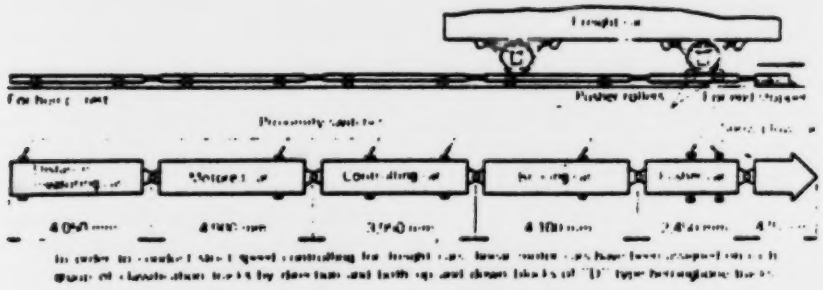


Fig. 4 Multiple-unit linear motor car

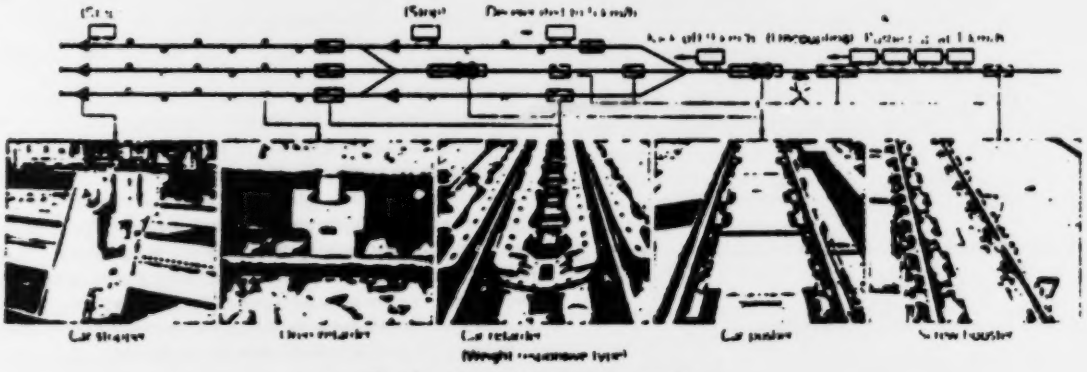


Fig. 5 Local classification works

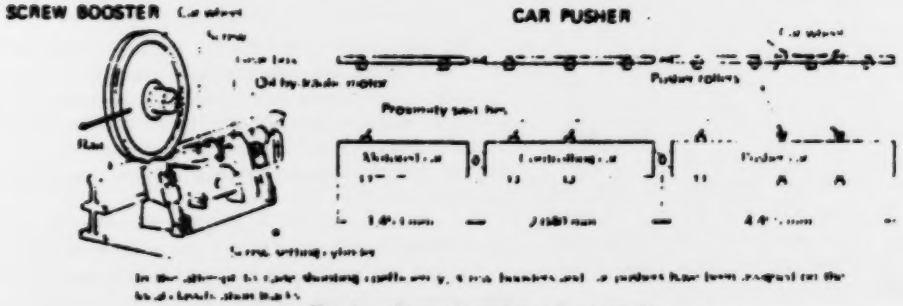


Fig. 6 Screw booster and car pusher

2. Data processing

In the past human hands were depended on to draw the basic plan of operations and set up work schedules. Also the information processing and change of works, both extending to minor yards near by, also depended upon manual work. This time those jobs are taken over by computer.

(3) Protection against cold weather

This yard is located in a snowy, cold district (Table-1), and it must be protected by special measure. In the automated yard, accumulated snow and the drop of outside temperatures increase the rolling resistance, causing difficulty in the movement of rolling cars and often causing them to halt on the way. Those are [illegible]

Fig. 7 Anti-snow devices

Table 1 Climatic data of the Kitakami District in Winter

Temperature						
Snowfall						

the movement of the linear motorcar and the function of the automation machinery to the extent that the operations of the yard come to a stop. Usually, a snowplow attached to the head of the locomotive is employed to remove snow, and diesel snowplow trains are used when the snow is deep. With automation equipment installed here and there, this marshalling yard does not permit the ordinary snow-removing method, so equipment has been specially developed to melt the snow. Pipes are laid on the gauge side and the field side of the track where the linear motor car moves along and hot water is passed through them. This method is called the hot water pipe heater system. Where the turnout or automation machinery are laid, hot air oil heaters are installed so as not to hamper the automatic operation. (Fig. 7).

3. Benefits of construction of the new marshalling yard

The following benefits are calculated from the construction of the new Kitakami Yard.

(1) Decrease of number of freight cars transshipped

Consolidation of services of surrounding minor yards into the concentrated yard operation at Kitakami enables a decrease in duplicated transshipment. By having the yard-pass train (direct trains skipping intermediary yards) take over the service by way freight trains, the number of cars transshipped is decreased by some twenty per cent.

(ncrease of proportion of direct shipment freight cars

The direct shipment cars, or through cars, are those which, unlike freight cars in general moved from one yard to another on the way, are sent direct to the destination station or yard. The construction of the Kitakami Yard raises the proportion of the direct shipment cars from the past thirty per cent or so to nearly seventy per cent.

(3) Shortening of train hour

Concentration of yard works and the decrease in reduplication of transshipment of freight cars by virtue of optimum timetable diagram operation lead to shortening of train hour.

(4) Transferable personnel and shunting locomotives are generated

Abolishment of some yards and concentration of yard works lead to wide reduction of personnel and shunting locomotives.

(5) Access of vacated land

The construction of the Kitakami Yard makes it possible to furnish the Shinkansen project with a stretch of right of way, which was already the immediate purpose of constructing the new yard.

4. In closing

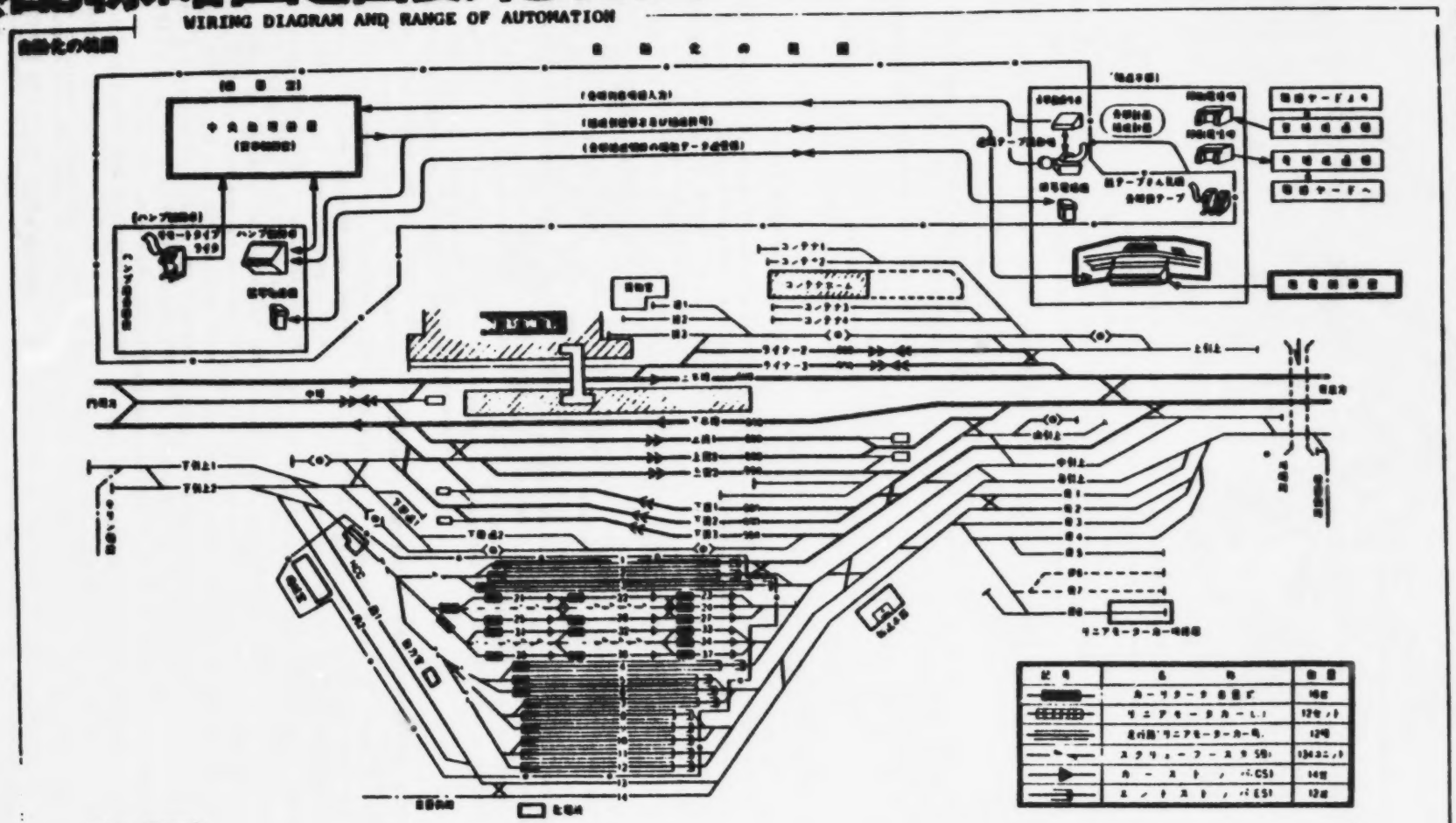
In about six years and at the cost of about twenty billion yen since October, 1978, the many efforts of those concerned to overcome every obstacle and difficulty have come to fruition. The Tohoku region, now has its first integrated automatic marshalling yard following suite of the Musahino marshalling yard of the Tokyo metropolitan region. Its operation began with the assignment of three hundred freight cars a day because of training of staff and adjustment of automation equipment. In the absence of any mentionable trouble the work was increased step by step. In October, 1979, freight handlings were completely transfered to the two big freight stations, Kitakami and Morioka much to the convenience of the nation's great project the construction of the Tohoku Shinkansen which is progressign steadily. Being the first automatic marshalling yard in the heavysnow district, it has had many unprecedented problems defying immediate solution and has not been entirely trouble free since full-scale operation has been started. Efficacy of the countermeasures against the cold weather has not been proven as yet, because the first winter it met (1978 ~ 1979) was exceptionally warm. We would like to pile up acquire experience henceforth and through that implement improvements to bring the new advanced marshalling yard up to the perfection and display expected as early as possible.

配線略図と自動化範囲

SOUTOMDA YARD

APPENDIX 7.6

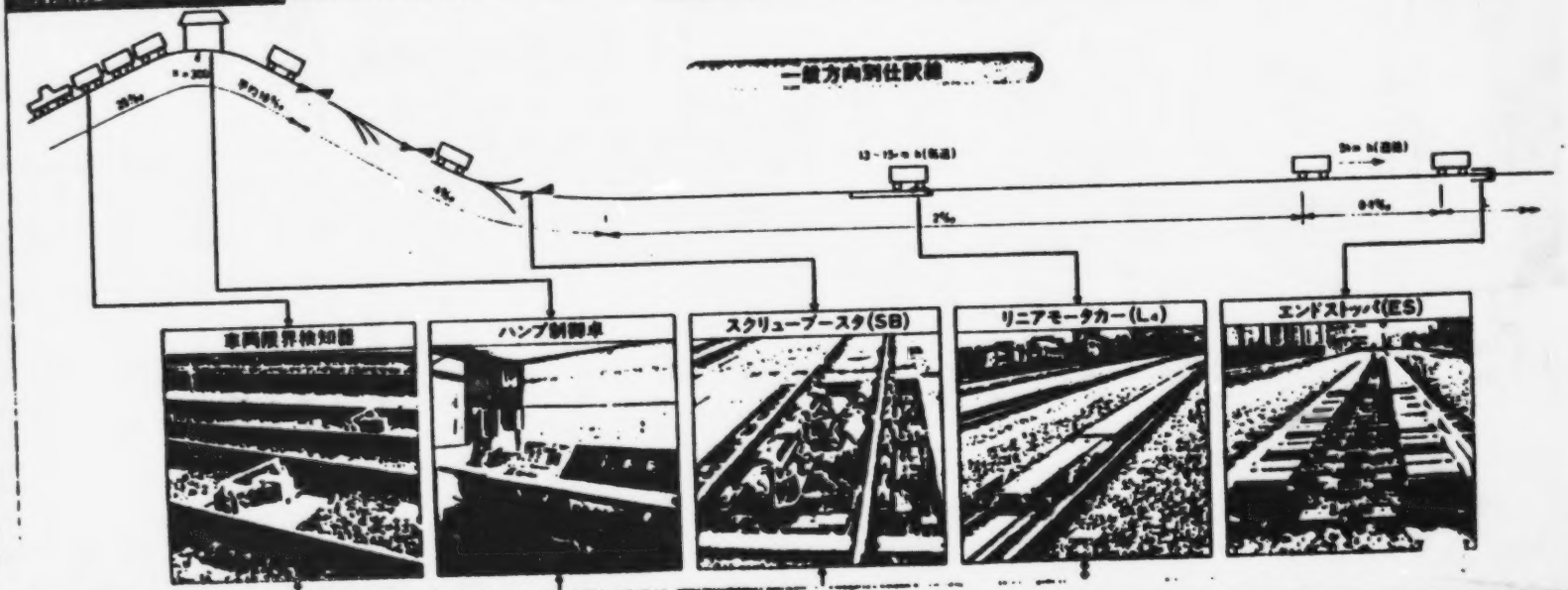
WIRING DIAGRAM AND RANGE OF AUTOMATION

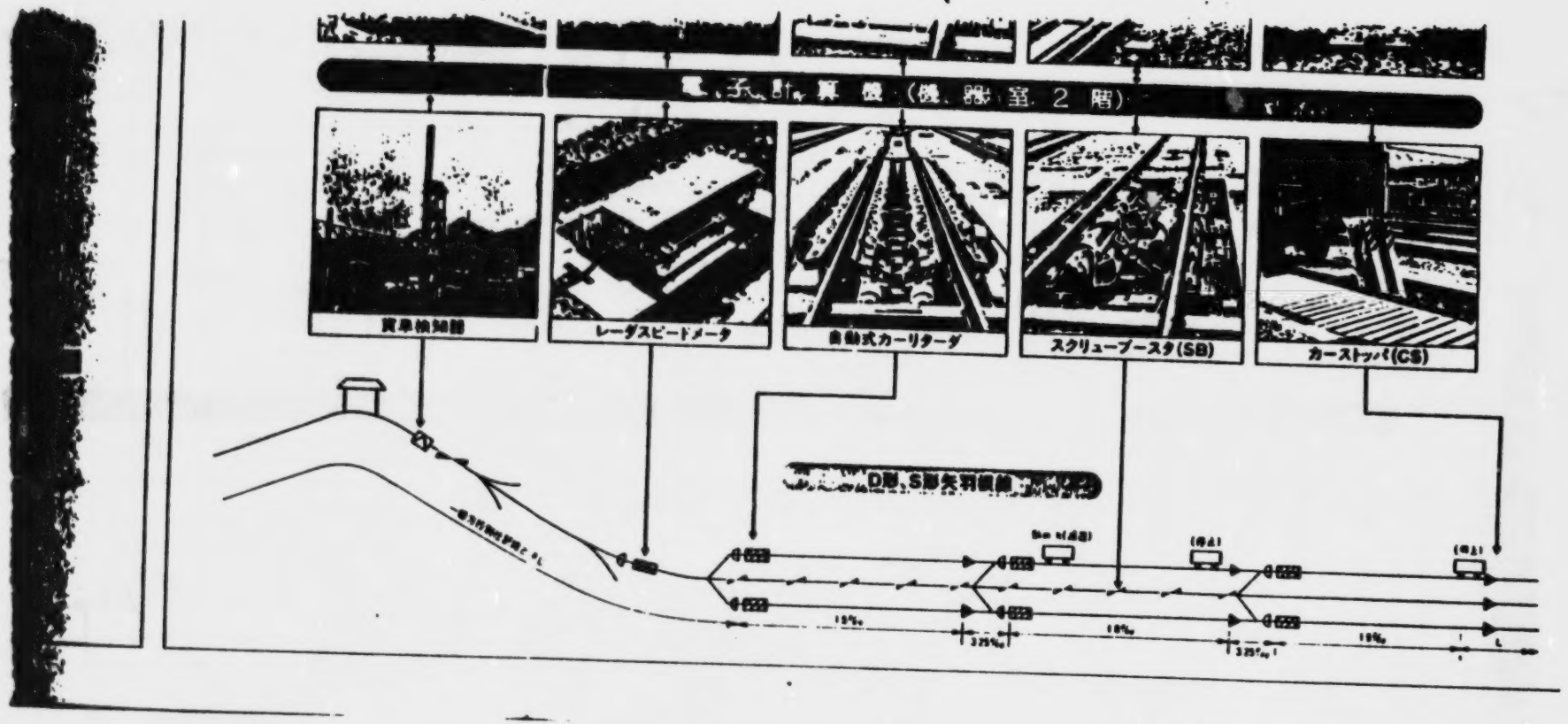


Flow Chart

ヤード作業の流れ

自動化システム構成図 Automatized System Structure




電子計算機（機器室 2 階）
貫通検知器
レーダスピードメータ
自動式カーリターダ
スクリューブースタ(SB)
カーストッパ(CS)
D形、S形矢羽根線路

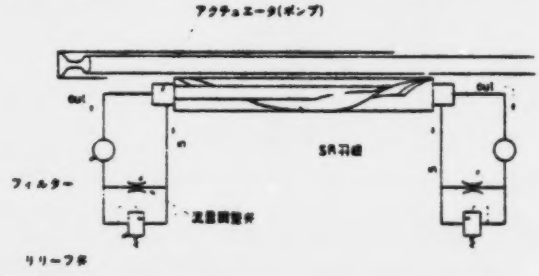
画期的な簡易システム!

SR(スクリューリターダ)

●原理は、フィン(羽根)に車輪のフランジ面を当て、フィンの勾配によって車輪に制動力を与えるもので、油圧バルブの調節により、設定速度以上の貨車は減速しますが、この速度以下の貨車には制動を与えず、すり抜けさせます。

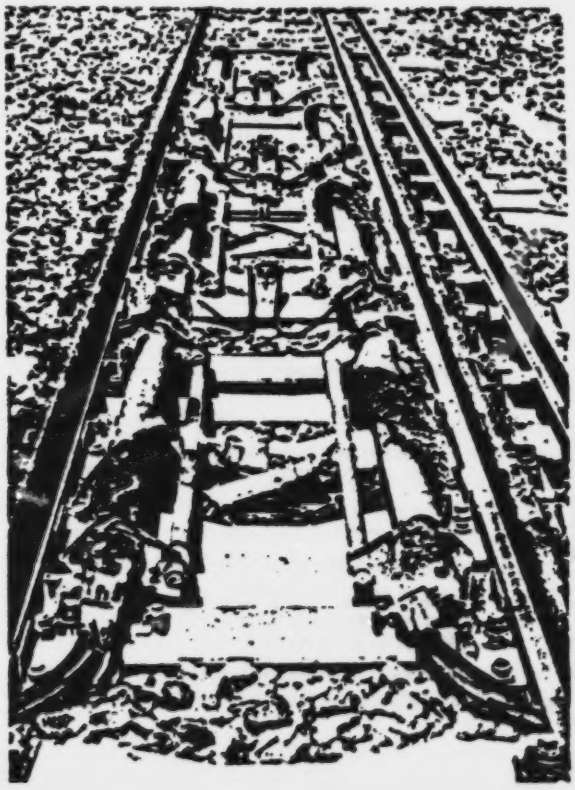
●単体制御を基本とし、外部からの信号は、入機進入の場合の起伏指令のみです。

●油圧機構であるため、故障が少なくなっています。



仕様

保合長	制動力	設定速度
1,400mm/本	600kg-m/本	5km/h

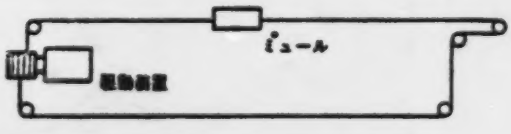


ORC(外軌形ロープカー)

●原理は、台車(ミュール)のプッシャーローラに車輪の踏面を当て、駆動装置の回転によるロープの移動で貨車を搬送するものです。

●ロープの正逆移動により、プッシャーローラが自動的に開放、格納する機能があるので、後続の散転に支障がありません。

●ローカル制御を基本とし、外部からの信号は駆動装置へのみ送るので制御が簡単です。



仕様

能力	搬送速度	戻り設定速度
1,500kg	5km/h	5or10km/h

GROPシステムとは　What is GROP System?

ゴムリターダ(GR)と力の強い内軌形ロープカー(IRC)をSROPシステムのように配置したのがGROPシステムです。GRは、騒音の発生がまったくなく、動力の必要もなく、しかも構造が簡単で、貨車重量に応じて制動力が得られるリターダです。

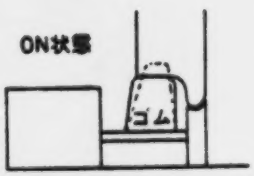
開発経過　History of Development

機器名称	開発工程 S49	50	51	52	53	54	55	設置可能箇所 仕訳線	受渡線	エンドストッパ
ゴムリターダ (GR)				試作試験 (工場・鉄道)	耐久試験 (鉄道)		実用機製作 (鉄道)	●	●	●
内軌形ロープカー (IRC)	連続用一方向形 模試作試験 (鉄道研究所・鉄道)			連続用 両方向形 模試作試験 (鉄道)			実用機製作 (鉄道)	●	●	

GR(ゴムリターダ)

●原理は車輪がゴムロール上を走行することにより、ゴムがたわみ貨車重量に応じて走行エネルギーを吸収します。

●設定速度になった場合、ゴムレールを降下させ貨車に制動を与えません。

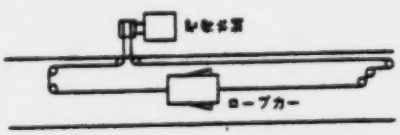


IRC(内軌形ロープカー)

●原理は、台車の2ヶ所のフランジャーローラに車輪のフランジ面を当て、駆動装置の回転によるロープの移動で貨車を搬送するものです。

●ローカル制御を基本とし、外部からの信号は駆動装置へのみ送るので、制御が簡単です。

●加速能力が大きい。

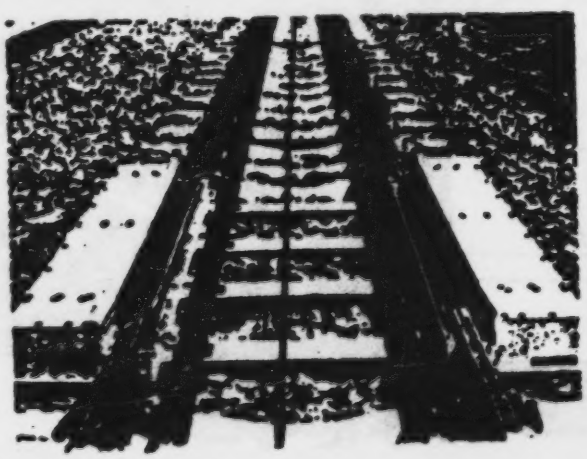


仕様

制動力	ゴム長	設定速度
60t/h	1m/本	5km/h

仕様

推力	搬送速度	取り設定速度
2,500kg	5km/h	5 or 10km/h



REVIEW

625.2-597.2 : 625.2012.3 : 624.1.44

Anti-snow Type Composition Brake Shoes for Wheel Treads

Kaname IDEMURA*

Composition brake shoes enabled trains to speed up on narrow gage, but they cause such a trouble as decreasing of brake effects during snow fall with an increased operation of high speed trains in snowy districts, so anti-snow type composition brake shoes have been developed.

As the result, the braking performances have been improved, but there arose some problems such as wear and thermal crack of wheel treads. The author is studying mainly countermeasures, but finds it very difficult to solve these problems.

This report intends to introduce the performance of anti-snow type composition brake shoes, discuss their problems and make further research.

1. Introduction

Composition brake shoes can control the frictional characteristics with materials, thus they are indispensable for speed up of trains, which have been operated at a maximum speed of 120 km/h since 1968 under the restriction of braking distance within 600 m in Japan.

Since electric cars with composition brake shoes were introduced in the snowy district, the braking effects tended to lower which is detrimental to brake performances.

Lowering of friction coefficient of composition brake shoes is caused by formation of water film as well as formation of ice layer through adherence of snow to the shoe surfaces. As a countermeasure for these troubles, the early practice was to make shoes lightly contact the wheel treads in running to prevent invading whirling snow; namely "anti-snow braking" was applied, but its effects were not enough. The measure tried next was to press the brake shoes against the wheel treads strongly in order to break-down melting water film of snow by frictional heat, but in this case excess thermal stress developed in the wheel. Thus efforts started for development of anti-snow type brake shoes mentioned below.

2. Construction of Anti-snow Type Composition Brake Shoes

A special feature of anti-snow type composition brake shoes is that water film is broken down mechanically by roughing friction surfaces with hard particles in the shoe materials.

For this purpose, great quantities of particles in the shoes which are harder than wheel material can elevate the performance of breaking down water film, but there are limits to the use of the shoes, because of increased wheel tread wear.

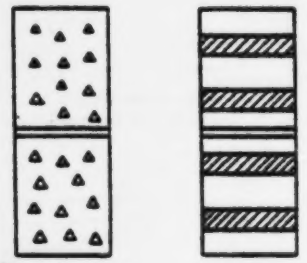


Fig. 1 Types of anti-snow type composition brake shoe

Constructions of anti-snow type brake shoes are classified into two types according to the composition of hard materials as shown Fig. 1. One is a dispersion type in which grains containing hard particles are dispersed into the composition shoe materials, the other is an insertion type in which blocks containing hard materials are inserted into the composition shoe materials. In the early periods of development, a homogeneous dispersed type was trialed, but it is not adopted now because of poor performance.

Development of anti-snow type composition brake shoes began in 1968 and now a 6th prototype HW6 is mainly in use.

3. Performance of Anti-snow Type Composition Brake Shoes

3.1 Friction characteristics

Friction characteristic may be the same as that of conventional composition brake shoes under dry conditions, but friction coefficient is set slightly high at high speed range considering a decrease in friction coefficient under wet conditions, and also small decrease in friction coefficient under wet conditions are allowed in the specification. The above mentioned anti-snow braking is applied about 100 daN of a shoe pressed force on the wheel tread in order to prevent insertion of whirling snow in running under snow fall conditions, therefore anti-snow shoes have only to be able to mechanically break down water film of melting snow and ice. Thus evalution of braking performance is done according to watering test results with a brake tester.

The results of evaluating the performance of early version of shoes HW1, in terms of the decrease in mean friction coefficient under watering conditions and dry conditions show that the decreasing rate of friction coefficient under the conditions of much quantity of water and of low temperature is large especialy at low initial braking velocity as shown in Fig. 2. Thus provide a criterion

* Car Braking Laboratory

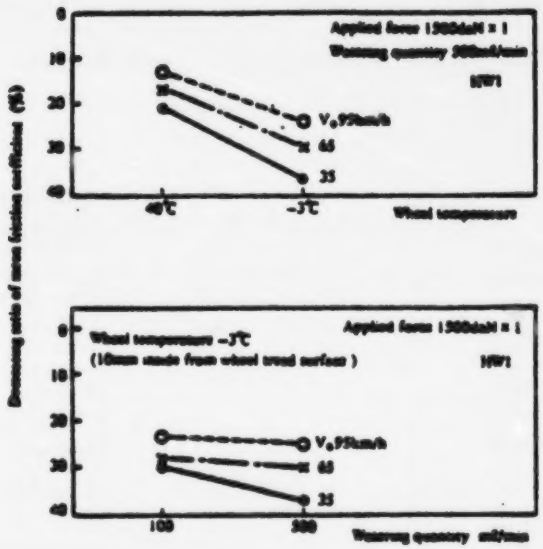


Fig. 2 Braking conditions and decreasing ratio of mean friction coefficient

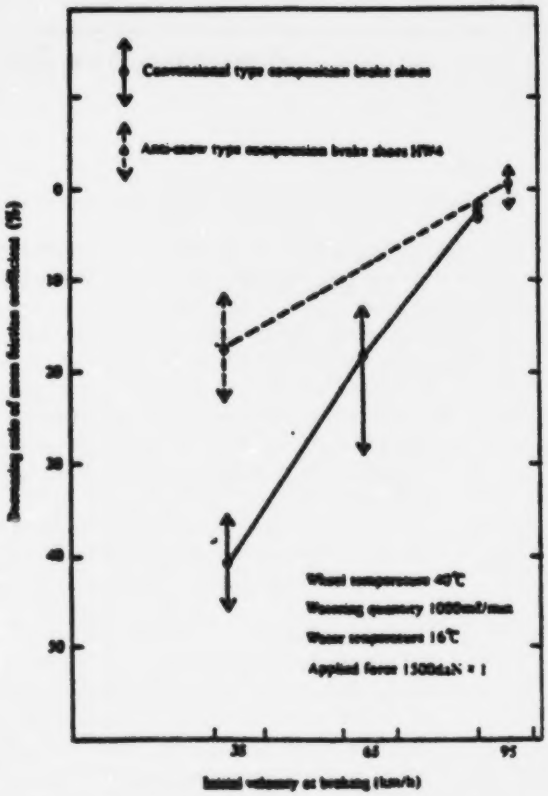


Fig. 3 Decreasing ratio of mean friction coefficient under watering conditions and dry ones between conventional and anti-snow type composition brake shoes. Bench test

for evaluation of anti-snow performances lowering characteristics of braking effects at low initial velocity.

As to the effects of anti-snow type composition brake shoes, a comparison of friction performances was made between conventional composition brake shoes and anti-snow ones under room temperature conditions in which a test could be done easily and rather stably, as shown in Fig. 3, which reveals that the decrease of mean friction coefficient under watering test condition as against dry one is apparently larger in the conventional ones, especially at low initial velocity.

It has been said that frictional braking distance at high initial velocity under snow fall conditions is longer three times than that on fine days under normal service braking, and about two times longer under emergency braking, but in the case of anti-snow type ones, an increase in braking distance is a mere 30~50 percent.

Dynamic braking is applied usually for normal braking of electric cars, therefore frictional braking with brake shoes in apply chiefly at low speed range where dynamic brake is in effective. As mentioned above, characteristics of large decrease of friction coefficient at low initial velocity are important. F-V characteristics of repetitive stop braking of initial velocity vo 35 km/h at a brake tester are shown in Fig. 4, which reveals that of conventional composition brake shoes, a large decrease of friction coefficient does not appear up to 8 repetitions, thereafter the decrease becomes large, but in anti-snow type ones the friction hardly drops up to 16 repetitions.

This is because the surface of conventional ones becomes increasingly smooth and water film come to be formed easily.

Mean friction coefficient of the conventional ones decreases to one third of that of anti-snow ones in more than 10 repetitions at vo 35 km/h.

In JNR the anti-snow performance of that brake shoes have break down effects of water film is evaluated by repeated watering tests at low initial velocity.

As mentioned above braking application of electric trains is controlled electrically at each cars and the operation of anti-snow braking is subjected to on-off control by switch to specified pushing force of brake shoe, but in passenger and freight trains hauled by locomotive the braking applications are not controlled electrically; it is difficult with these train to apply the anti-snow braking in the same way as with electric cars, therefore whirling snow in running comes to be deposited on the frictional surface of shoes.

Supposing this case, comparison was made between the case of applying the brake after allowing the snow to invade with the top of shoe exposed 25 mm, as indicated Fig. 5 and the case of doing the same without allowing the invasion of snows.

In the case of allowing the invasion of snow a very large drop in the friction happened, especially at low initial velocity. In actual operation, train use a comparatively light brake application, that is preliminary braking, just before normal brake application, in order to melt deposited snow.

Results of brake performance test of super express electric trains under snow fall are shown in Fig. 6. Braking distance in emergency application at initial velocity of 120 km/h was 450 m under the snow conditions without

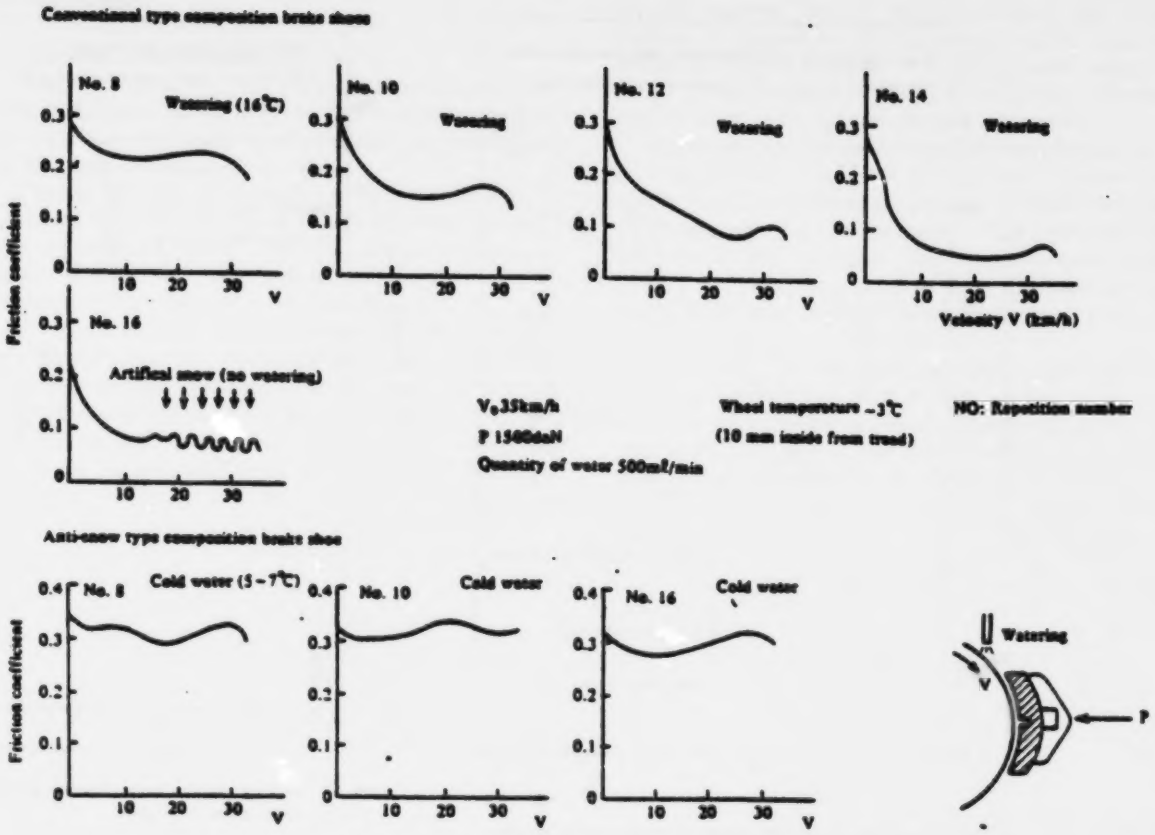


Fig. 4 F-V characteristics on repeated brake test of composition brake shoes at low initial velocity. Brake tester

snow whirling and 540 m under the conditions with severe snow whirling in running. Braking distance lengthens by about 20 percent when anti-snow braking is applied.

The friction coefficient of shoes estimated from retardation of train is shown in Fig. 7 and it coincides which the bench test results approximately. In the experiments of this train, anti-snow type brake lining for disc brake devices of trailer cars is used.

3.2 Wear characteristics

Wear of anti-snow composition brake shoes is large because of the friction being due to rough surfaces of mating wheel treads and wear of them under dry conditions permits a little more than that of the conventional composition brake shoes.

But wear of them in winter is closely associated with hollowing wear of the wheel.

4. Influence on Opposite Wheel Treads

Anti-snow type composition brake shoes inevitably increase the wear of wheel because they roughen the surface of mating wheel treads; as a results, hollowing wear of wheel treads occurs.

This trouble is caused by the phenomena that worn dust of wheel deposited on the shoe surfaces grows up to a nucleus which unilateral adheres and abrodes the wheel surface.

The hollowing wear of wheel cause unpleasant jolting of car and fattening of the wheel flange.

This hollowing wear has a relation to anti-snow braking, in addition to stopping brake and there is a linear correlation between falling snow quantity and increase in hollowing wear of wheel treads. Because hollowing wear of wheels does not appear except in winter, it seems that presence of water on frictional surface of shoes plays a part in this wear.

Increase in the hollowing wear of wheel means an increase in transfer amount of metal matereals to the shoe surfaces. These fat inclusioned metal particles on shoe are heated by friction, fite into the shoe material breaking thermally shoe surfaces and are moved by friction force, forming thereby deep grooved wear on the shoe surface. Therefore wear of wheels per 10,000 km in running increases in proportion to wear of shoes as shown in Fig. 8.

Because hollowing wear of wheel in winter is a serious problem for car operations the countermeasure for this problem have been studied since the beginning of the development of anti-snow brake shoes. Though harding of shoe surfaces would be effective to prevent wear dust of wheel treads and others from cutting into shoe surfaces, a new problem arises that is heat cracking which is produced by poor contact of shoe surfaces with wheel treads. So above mentioned countermeasure for hollowing wear of the wheel treads is difficult to take at present. However thermal cracks of wheel treads diminish when the wear of wheel is

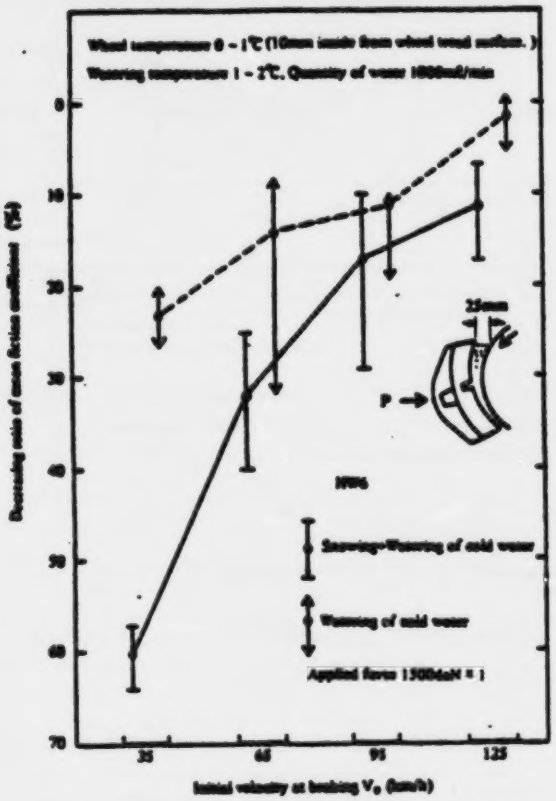


Fig. 5 Decreasing ratio of friction coefficient of anti-snow type composition under the condition of brake shoe with snow between shoe surface and wheel tread and under dry condition

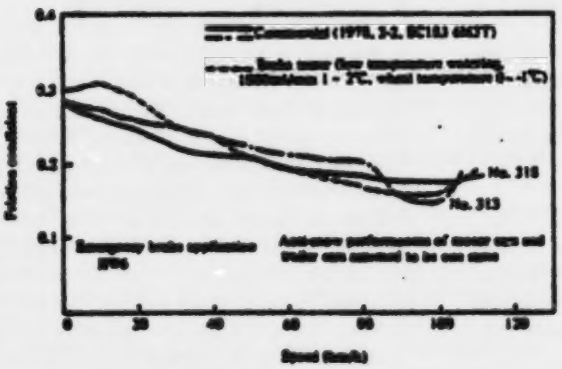


Fig. 7 Friction coefficient of anti-snow type composition brake shoe in the commercial service and at the brake tester

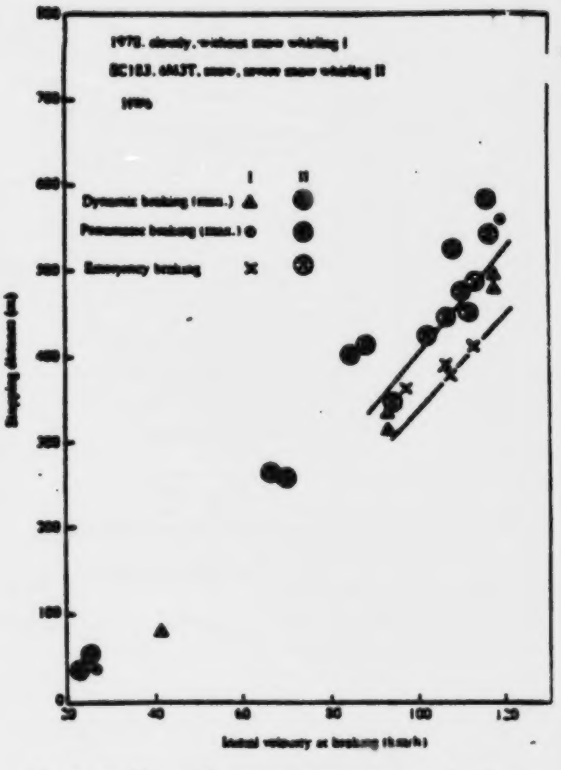


Fig. 6 Braking performance of super express electric cars under snow conditions

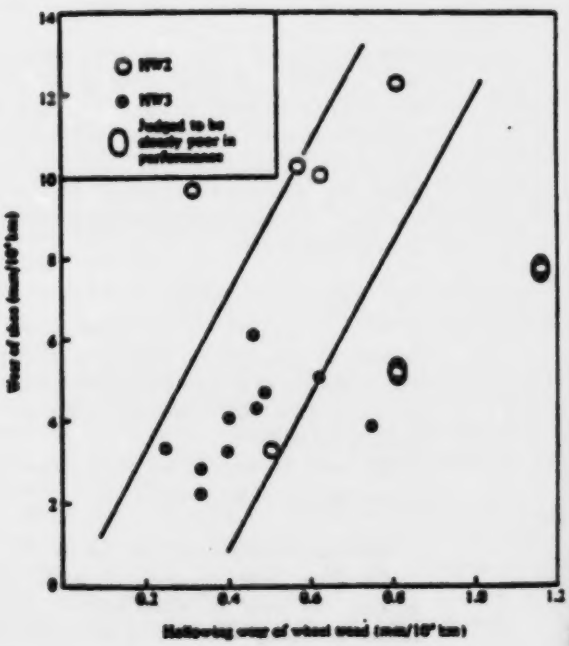


Fig. 8 Wear of wheel tread and shoe

increased to some extent. At present the countermeasure is being sought in the direction of hardening the shoe surface to some extent.

5. Direction in Future Research

Usage of anti-snow type composition brake shoes has never been heard except in JNR. This is probably because the train operation under snow conditions can not be met by the brake handling alone in Japan.

Further elevation of anti-snow performance of shoes is found to result in an increased hollowing wear of wheel tread as explained before, which may lead to a skidding of wheels in snow fall. Thus such a measure would not be recommendable under the present situation.

As to the hollowing wear problem of wheel tread, as mentioned before, the countermeasure proposed is likely to promoto thermal cracking of wheel tread, so friction material is required to satisfy both properties of providing a hard shoe surface and being easy to fit the wheel tread which are features conflicting with each other. Therefore the only alternative at present would be to tolerate an increased wear of wheel to some extent.

In future research it would be important to establish the relation between friction material property and wheel damage, to improve the friction material and to study the profile of friction surfaces. It is indispensable matter to seek a correspondance in occurence condition of hollowing wear of wheel between bench test and service test.

At present, another countermeasure for hollowing wear of using sintered alloy shoes is being tried. This material causes very little hollowing type wear of wheel tread, but in seasons other than winter makes a little more wear and hair cracks than composite ones. Improvement in this point is now going on. Improved shoes cost high and they would be required to exhibit better performance justifying the cost.

As to the disc brake shoes for trailers, their adoption has been delayed because of a wear problem in the disc under use of anti-snow type shoes. Developmental tests are now under way so that they can be utilized for improvement of brake efficiency.

28.2—897.2 : 621.762

Performance of Sintered Iron Based Metallic Brake Shoes for Tread Brake —Some Investigations by Full Size Brake Tester—

Kaname IDEMURA*, Yoshimi SASAKI*

1. Introduction

A trial was started to introduce sintered alloy friction materials (copper and iron based) for railway vehicle brake shoes in 1958, and brake performance tests have been carried out by brake tester since then. In early stage they had some problems on friction and wear performance and no special superiority compared with the composition shoes. Afterward their following characteristics have been obtained through the many developments.

(1) Easy controll of friction coefficient.
(2) High endusrance in thermal strength, stability of friction property over high speed range.
(3) Superiority of anti-wear property.
(4) Superiority of anti-snow performance.
(5) Mild attack against mating metals.

From these superiorities, electric cars in the SHINKANSEN have adopted formally the sintered cupper-based friction materials for disk brake since 1964. On the other hand, the development of iron-based ones has started to keep pace with the copper-based ones. As this friction speed dependency resembles to adhesion characteristics, this materials have been used tentatively for tread brake shoes at private rail way since 1963. In JNR this application has been examined to cope with the problems of hollowing wear on wheel tread and reducing brake effects under snowing condition in winter.

This paper reports the results of the tests which were carried out by full size brake tester on friction performance of sintered iron-based brake shoes developed.

2. Test Materials

(1) Brake shoes

Sintered iron-based brake shoes for tread brake, A—5060.

(2) Wheels

One wear wheel for electric cars.

3. Test Methods

In the test specification of JRS, some parts of schedules of test were amended and carried out according to that as shown in Table 1. Moreover the test code d_3 and d_4 aim to investigate anti-snow performance, setting a low temperature box and watering devices as shown in Fig. 1, using LN_2 for cooling medium.

Table 1 Test schedule

	Test code	V_0	P	S	Wheel temperature	Water test	Note
1	b	65 85 95	1.5ton 0.5ton	25	40°C	-	Dry
2	d_3	65 85 95	1.5ton	20 5 0	40°C	0 0 0	
3	d_3	65 85 95	1.5ton	0 0 0	40°C	-	1)
4	d_3	65 85 95	0.5ton	0 0 0	40°C	-	
5	d_3	- 35 -	1.5ton	20	40°C	-	
6	d_3	65 85 95	1.5ton 0.5ton	0	- 0°C	-	2)
7	d_3	- 35 -	1.5ton 0.5ton	0 0	- 30°C - 20°C	-	3)

Note: 1) Watering on the low temperature wheel 500 cc/min 15°C
2) Watering on the low temperature wheel 1000 cc/min loading of ice on the shoes
3) Watering 1000 cc/min temperature of water 16°C

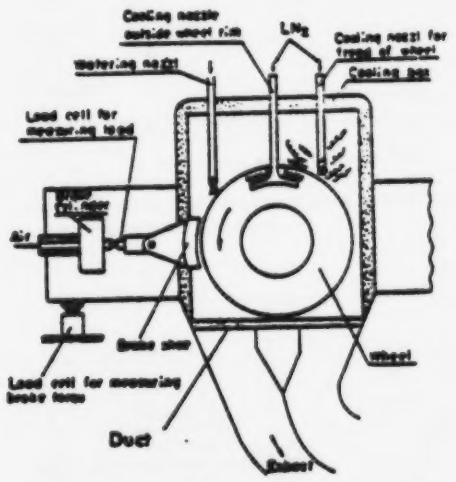


Fig. 1 Cooling box and watering devices

4. Test Results

(1) Friction performance

(a) At the b code test under dry conditions (initial speed and shoe load are examined in random combination) friction speed dependencies satisfied fully the specification of anti-snow type composition brake shoes, and fluctuations of the performance are small.

(b) At the d_3, d_4 code test under watering conditions, friction speed dependencies also satisfied the specification. But only in case of low load (1.5 ton, d_4 code), friction coefficients at V_0 35 km/h were slightly lower than under dry conditions. On the contrary at V_0 65 and 95 km/h these have a upward tendency, especialy maximum at 65 km/h which were about 11 percent upward than under dry conditions.

* Train Operation Laboratory

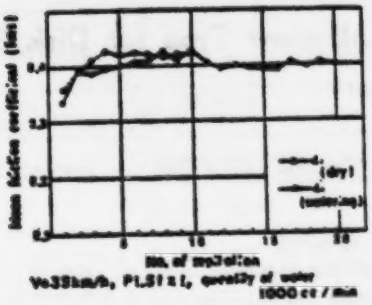


Fig. 2 Comparison of friction coefficient under dry and wet condition at low initial velocity

(c) The results under normal temperature watering test (d_4 code) at low initial speed (V_0 35 km/h) present a good anti-snow performance that does not show a lowering tendency of friction coefficient with 20 times repitation test as shown in Fig. 2.

(d) The results under low temperature watering test (d_5 code) where wheel tread temperature of -3°C at 10 mm below of tread using LN_2 were satisfied for the specification values as in case of normal temperature watering test. But friction coefficients at low initial speed (V_0 35 km/h) under low shoe load (1.5 ton) were 27 % less than those in case of dry test. In the both case of V_0 65, 95 km/h and high shoe load (3.5 t × 1) we obtained higher friction coefficients among every initial speed than under dry conditions. These have the same tendancy as normal temperature watering test results.

(e) In the case of low temperature test (d_6 code) intering ice particles to the shoe surface, at V_0 95 km/h under $-16 \sim -20$°C of wheel temperature, the friction coefficients in initial stage of braking are 0.02—0.03, i.e., nearly non-braking state, but when the ice melts the friction coefficients rise rapidly according to the rise in wheel and shoe temperature, being satisfactory for the specification as shown in Fig. 3.

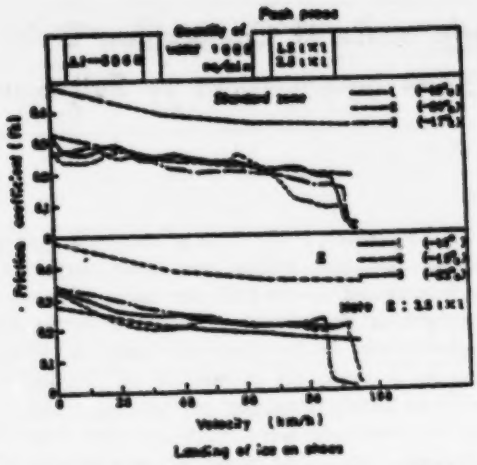


Fig. 3 Velocity dependency of friction coefficient

(2) Wear of shoes

Wear quantity of shoes were tested under dry condition (d_1 code). The wear of shoes is not much under every initial speed stage and nearly half compared with that of anti-snow type of composition brake shoes formerly tested.

(3) Effects on mating material (wheel tread)

(a) Small red bands were seen at V_0 95 km/h. After stop some hot spots were also seen, but these were diminished by next braking. Therefore this does not give remarkably bad effects on wheel as far as this test condition range is concerned.

(b) As for aspect of wheel tread after this test condition, the wheel tread is likely amooth, and adhesived shoe materials (Cu) were seen slightly. This feature is desirable to increase adhesion effect on wheel and rail interaction.

5. Further Subjects

Friction performance of sintered iron-based brake shoes satisfies the test specification of antisnow type ones, which has the excellent anti-snow performance, anti-wear characteristics, and no bad effect on mating materials, but has some points to be improved as follows.

(1) There are some strip off shoe surfaces under watering test. This phenomenon likely became bad effects on wear. Therefore its further improvement is needed.

(2) At b code test under dry conditions at V_0 95 km/h, small hot spots were seen on the wheel tread. Under the more higher speed condition, it is afraid that this phenomenon becomes more remarkable, producing hair crack on wheel tread. Therefore the further improvement of material is desired to remove the phenomenon.

(Pre. Report No. 5, 1977)

625.2—897.6.001.4 : 625.2—892.133 : 624.144

Performance of Composition Brake Shoes of Anti-snow Type for Disk Brake —Some Investigations by Full Size Brake Tester—

Kaname IDEMURA*, Yoshimi SASAKI*

The composition brake shoes of anti-snow type were developed for disk brakes and their performances were investigated by the full size tester, for the use of conventional composition brake shoes during snow-fall often results in the significant decrease of brake force. As a result, the decrements of friction coefficient with newly developed composition brake shoes under wet conditions were much less than those with conventional ones. The wear of composition brake shoes of anti-snow type was comparable to that of conventional ones. However, the wear of brake disks tended to increase in some degree. The test procedure for the anti-snow performance of brake shoes was found through these tests.

1. Introduction

With the enlargement of the use of composition brake shoes mainly for electric cars, the decrease of brake force during snow-fall has appeared as a trouble of train operation. It results from the freezing of the frictional surface of braking shoes during running on snowy lines.

As one of the countermeasures against the trouble the following method has been employed, that is, applying a brake force to some degree while a train is running to increase the temperature of both braking shoes and wheel treads and to break thermally down the freezed layer and melted water.

However, this method with conventional shoes results in putting excessive heat burden and leads to a heat damage on wheels. In order to remove such a trouble it was intended to develop the composition brake shoes with properties preventing the formation of ice film on the surface of brake shoes by applying a weak brake force (pressure of brake cylinder : 0.4 ~ 0.6 kg/cm² or shoe load : 30 ~ 100 kg) and breaking mechanically the lubricating water film that causes the friction coefficient to decrease.

The composition brake shoes for a disk brake under the test were developed on the basis of the same conception with those of anti-snow type for a tread brake.

The purpose of this test is to search into the performances of the brake shoes of anti-snow type as compared with those of conventional types, as well as to investigate the test method for anti-snow performances under wet conditions based on the present test code (JRS).

* Train Operation Laboratory

2. Test Method

The testing machine used for the investigations of anti, snow performances is a full size brake tester of momentum type with 6.7 ton of the equivalent weight per one wheel. The employed brake disk is of side disk type for diesel cars made of cast iron. The kinds of tested brake shoes are one of conventional types (RD—10) and six anti-snow types of composition shoes. The brake lining consists of three segments per one brake shoe. The characteristics of the tested shoes are shown in Table 1.

The tests were carried out under wet conditions, as well as dry ones based on JRS in order to investigate anti-snow performances of the developed shoes. The test with a shoe of conventional type was intended for clarifying the cause of drop of friction coefficient under wet conditions and examining the recovering characteristics of friction coefficient after restoring to dry conditions. Water at room temperature was sprayed uniformly into the inlet side of the shoe to the rotating direction of the wheel.

3. Test Results

3.1 *Friction performance*

Concerning the friction coefficient during the JRS b-code test under dry conditions (Ref. Table 2), almost all kinds of composition brake shoes of anti-snow type revealed a little higher coefficient than the upper limit of the standard value designated by JRS at the initial speeds faster than 65 km/h. On the contrary, the conventional shoe showed a little

Table 1 Testing shoes

Name of linings	Structual feature
RD-18 A	I : Cu-sintered alloy II : Conventional resinoid material
DW-31	I : Conventional resinoid materials II : Special resinoid material including compounds for anti-snow
DW-B 21	The same kind with RD-18 A
DW-H	I : Conventional resinoid material II : Special resinoid material including compounds for anti-snow
DH-H-1	The same kind with DW-H
DW-H-2	The same kind with DW-H-1
RD-10	I, II : Conventional resinoid materials

Table 2 Test schedule

Type of lining	Test code	Initial speed V_0 (km/h)	Force per brake block (t)	Quantity of water (l/min)	Number of repetition
Snow type Conventional type	Dry condition JRS-b code	35, 65 95, 125	2.5 × 2	2.0 × 2	17
〃	Constant velocity V_0 wet condition (No. 1)	〃	〃	〃	3 Any V_0
〃	Constant velocity V_0 wet condition (No. 2)	35	〃	〃	20
Conventional type	Alternation of wet & dry condition	〃	〃	〃	5 for wet 9 for dry
〃	Recovery often wet condition	〃	〃	〃	3 for wet 21 for dry
〃	〃	35, 65	〃	〃	3 for wet 10 for dry
〃	〃	35, 95	〃	〃	5 for wet 10 for dry

lower value than the standard at the initial speed of 95 km/h. These differences of the performance are considered to be the effect of compounds included in the shoes.

In the tests with constant initial speeds under wet conditions (Test No. 1), two composition shoes of anti-snow type, that is, RD—18 A and DW—B 21, showed a little lower friction coefficient than the lower limit of the standard value. On the other hand, the coefficients of those shoes of other types approached the designated value. The conventional type of shoe revealed a significantly lower friction coefficient than the lower limit of standard value.

Dropping ratio of the mean friction coefficient, f_m, under wet conditions to that under dry conditions is larger with both the conventional type and the anti-snow type of shoes developed earlier, as shown in Fig. 1. The dropping ratios of recently developed five types of composition brake shoes of anti-snow type are less than 20 per cent. The tendency of the dropping ratio of f_m to decrease at the initial speeds beyond 65 km/h in all composition brake shoes other than DW—31 is attributable to the break down of lubricating film by heat.

From the test results under dry conditions at the constant initial speed of only 35 km/h (Test No. 2), the drop of the friction coefficient became significant by the repetition of brake application under wet conditions particularly just after applying the brake, both with RD—10 and RD—18 A, as shown in Fig. 2.

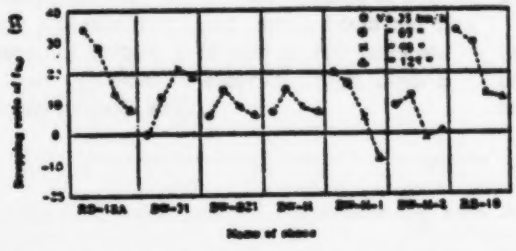


Fig. 1 Dropping ratio of mean friction coefficient at constant initial speed under wet condition (No. 1)

Under the tests at lower initial speeds, it might be considered that the mechanical break down of water film by the rough surface formed with abrasive compounds of the shoe material than the breakdown of the film by heat contributes to the improvement of frictional performances. After the repetition of applying a brake at the lower intial speed with conventional composition brake shoes, the surface of shoes becomes smoother as shown in Fig. 3 and it leads to the easier formation of lubricating water film. Consequently the friction coefficient just after applying a brake at higher speeds tends to decrease. The smoothing of the frictional surfaces with conventional composition brake shoes is considered to result from the so-called "lapping" action with water.

The change of friction coefficient with conventional shoes in altering the test condition repeatedly "wet" after "dry" is shown in Fig. 4. The friction force recovered considerably under dry conditions and the friction coefficient tended to increase to some degree with the number of repetitions From this result it is shown that the application of a brake under dry conditions contributes to the prevention of smoothing of the frictional surface.

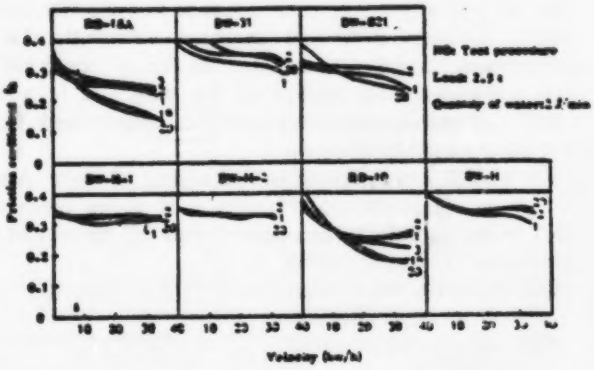


Fig. 2 Friction coefficient on applying repeatedly a stop brake under wet condition

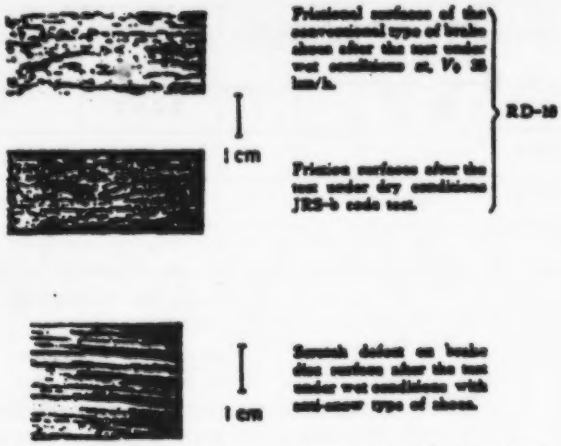


Fig. 3 Frictional surfaces of shoes and disk after tests

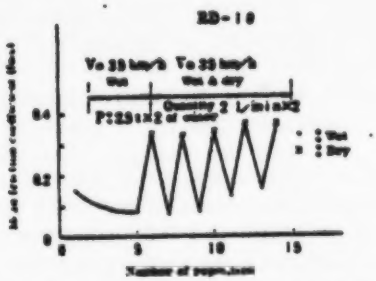


Fig. 4 Mean friction coefficient (fms) on alternating wet & dry condition

3.2 *Wear performance*

From the results of the combination tests at several initial speeds (JRS—b—code), the wear quantities of the composition brake shoes of anti-snow type were almost equal to that of the conventional shoes, except that two anti-snow types of shoes, that is, DWH and DW—H 1 with the homogeneous property of abrasive compounds, worn a little more than the conventional one. But the wear quantities with all tested composition shoes of anti-snow type were under the standard value of JRS (Fig. 5).

The wear of both the shoe and the disk generally increases under wet conditions. After the test under wet conditions a number of linear scratches were found on the surface of the disk. It is a matter of degree that these scratches might lead to some trouble.

The transfering and attaching of wear debris of disk material on the surface of shoes often causes the significant increase of wear of disks and shoes

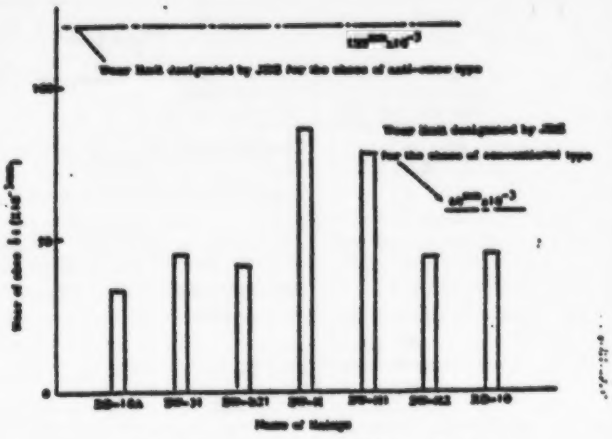


Fig. 5 Wear of shoe at JRS-b code test

metal pick up. The anti-snow types of composition brake shoe include some abrasive compounds as the frictional material and so they tend to abrade the surface of disks. Therefore, it becomes particularly important to investigate what kind of compounds should be included in the composition shoe of anti-snow type.

4. Concluding Remarks

As the linings of shoes for the disk brake are used as segments, they possess the merit of choosing freely the friction materials.

Concerning the performance of the developed composition brake shoes of anti-snow type, the decrement of friction coefficients under wet conditions are much less than that of the conventional composition brake shoes and the smoothing phenomenon of the frictional surface is not found even after the repetition of brake application under wet conditions, in contrast with the conventional types.

It is necessary for the composition brake shoes of anti-snow type to possess such a property as to form a rougher frictional surface and break the water film mechanically. Therefore, the fact that friction coefficient does not decrease after applying repeatedly brakes at a lower speed, for example, 35 km/h can serve as one of the standard for the anti-snow performances.

The wear of composition brake shoes of anti-snow type is comparable to that of conventional composition brake shoes, but sometimes the wear due to abrading the surface of a mating material, namely a disk, might increase to some degree.

(Pre. Report No. 94, 1973)

625.2—897.2 : 625.2.012.3 : 625.2.033.373

Study on Occurring Condition of Metallic Inclusions in Anti-snow Type Composition Brak Shoes which cause the Hollowing Wear at Wheel Treads

Kaname IDEMURA*, Tetsuji YAMASHITA*

1. Interduction

As a countermeasure for the decrease of the brake effect in snow fall, the composition brake shoes of anti-snow type have been developed. More over, the anti-snow braking was applied in order to prevent intervention of snow and formation of frozen layer between brake shoes and wheel treads. As a result, brake effects were improved in snow fall. On the contrary, hollowing wear at wheel treads due to metallic inclusions of brake shoes was increased. In order to study the occurring condition of this metallic inclusions, experiments were done using a testing machine.

2. Test Method and Results

The test was carried out by the inertia type brake testing machine in $1/\sqrt{2}$ size of actual system. Applied load to the shoes is about 0.5 kg/cm² and friction speed is 65 km/h of constant speed, simulated the actual vehicle conditions of anti-snow braking that is used during snow fall. To search for the occurring condition of metallic inclusions on the interface of friction surfaces, quantity of spraying water was controlled.

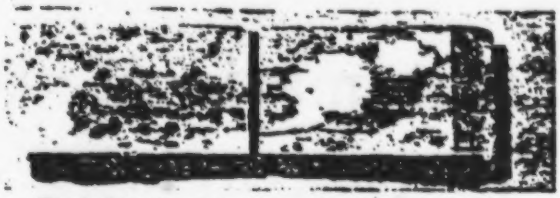


Fig. 2 Metallic inclusion in the brake shoe surface

Our results showed that metallic inclusions were not found under the lubricated condition for much supplied water but were found evidently under the boundary one. When once metallic inclusions occured, the friction force and temperature rise of wheel grow up as shown in Fig. 1. Metallic inclusions grow up as shown in Fig. 2 and fall off from the shoe surfaces in some grown size, remarking pitted marks on them. Metallic inclusion appeared likely to occur under the condition that water film of shoe surfaces break down thermally: in wheel temperature 45—60°C at 10 mm below from tread surface and in wheel tread surface temperature 80—100°C.

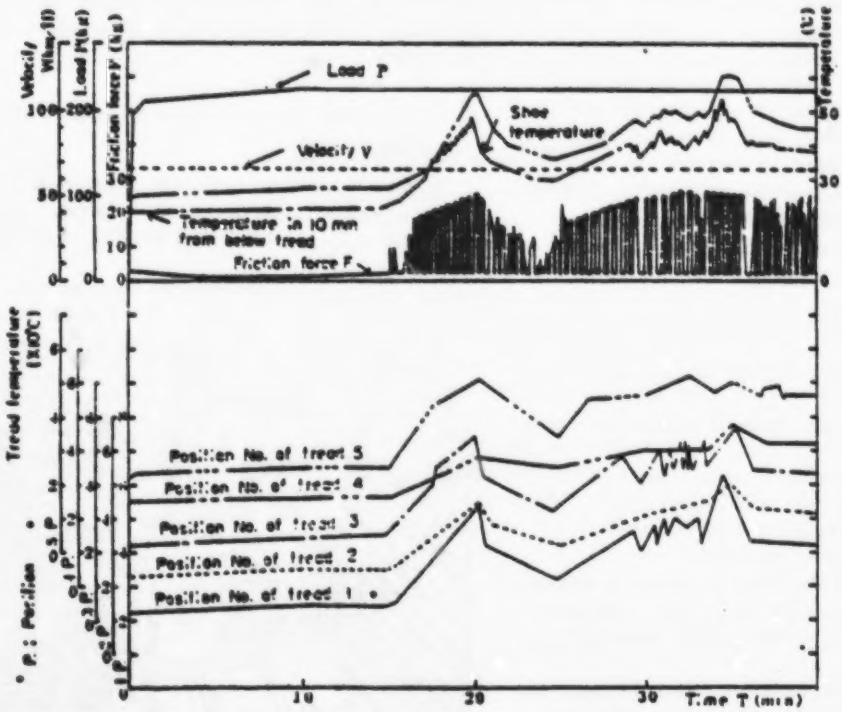

Load P
Shoe temperature
Velocity V
Temperature in 10 mm from below tread
Friction force F
Position No. of tread 5
Position No. of tread 4
Position No. of tread 3
Position No. of tread 2
Position No. of tread 1
Time T (min)

Fig. 1 Friction force and temperature rise when metallic inclusion occures

3. Consideration of metallic inclusions occurring mechanism

Wear debris of composition brake shoe surfaces play a role to prevent the occurrence of metallic inclusions. In the presence of water streams, these debris are washed out and reveal some pockets in shoe surfaces. When wear particles of wheel were thrown into its pocket, these iron particles became a core for the metallic inclusions. These are harden by quenching under friction heating and presence of water. Thus hardened particles make the opposite wheel treads wear on one side.

Above reasonings of metallic inclusion occurring mechanism give a support to ORE's reports.

(Pre. Report No. 25, 1976)

* Train Operation Laboratory

Automatic Measuring System for Pantographs and Wheels of the Shinkansen Electric Cars

1. Preface

Since 1974 the JNR Railway Technical Research Institute has conducted fundamental research and technical development for a system such as will permit the automatic measurement of various dimensions of pantographs and wheels of the Shinkansen electric cars as they run through the system. Such system, manufactured on an experimental basis, is now being tested for confirmation of its functioning on actual cars on the Shinkansen General Test Line and will be further studied and examined for practical use.

A brief explanation of the circumstances and results of the development of this system follows.

2. Purpose of development

In view of the high-speed operation (maximum speed: 210 km/h) of Shinkansen electric cars, any failure in pantographs or wheels may result in a serious accident. For this reason the condition of pantographs is checked at daily pre-service inspection, and various dimensions of the wheels are measured and the state of their treads are inspected at the time of periodical inspection, for ensuring their safety.

By automatizing such daily inspection and measuring work, this system is intended to establish the constant supervision of the respective parts and further improve the accuracy of inspection and the safety.

3. Organization of the system

This system is composed of the following seven measuring devices:

(1) Device for detection of wear of the pantograph pan (slide plate)
(2) Device for measuring the push-up pressure of pantograph
(3) Device for detection of wear of wheel treads
(4) Device for detection of wear of wheel flanges
(5) Device for measuring the wheel back gauge
(6) Device for measuring wheel diameter
(7) Device for detection of abnormal vibrations in wheels.

These devices are to be installed at the following places:

(1) & (2) near the entrance or exit of the inspection and repair shop
(3) to (6) on the deadhead transition track between the main track and the inspection and repair shop
(7) on the main track.

These devices detect and measure respective items together with the car number, as the train passes through each of these devices.

Data obtained by these measurements are transmitted through cables to the processors in the car depot and processed in real time according to the nature of each data, and then are printed out in accordance with a given format. Any item which has exceeded specified limits is marked, for example, by printing in red to indicate of the necessity of inspection and repair.

For each of the measuring devices (1) to (7), the fundamental type has already been fully developed, and will be improved for actual use after reviewing the results of tests on the Shinkansen General Test Line.

At the present stage the processing of the data obtained by each of the measuring devices is performed individually and separately, since the data are different in nature and in the processing method applicable to it, but in future unified processing is to be studied to develop a centralized processing system.

4. Functions and principle of operation of measuring devices

Each of the measuring devices is shown in Table 1 with functions and principle of operation. In Fig. 1 their arrangement, and in Photos 1 & 2 their installation are shown.

Moiré camera on the device for measurement of wear of pantograph pan

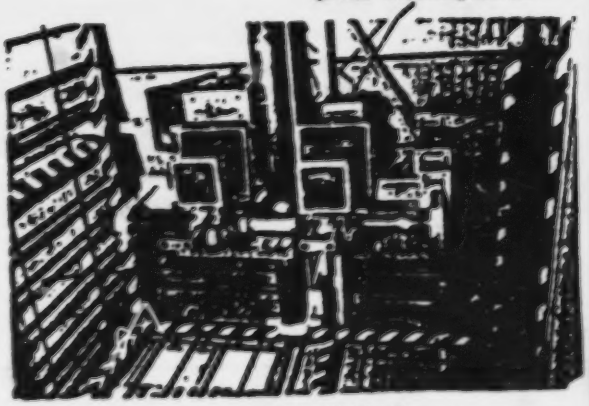
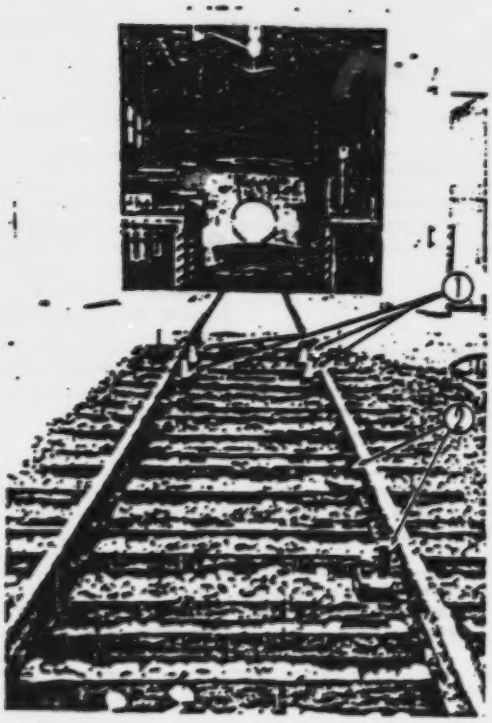


Photo 1 Installation of Moiré Camera



① Device for measurement of wheel back gauge
② Wheel sensor for detection of car speed

Photo 2 Installation of Gap Sensor

5. Future development

Each of the measuring devices is now being progressively tested for confirmation of its functions in the Shinkansen General Test Line. In the future the test results will be fully evaluated, and review and study will continue to achieve actual use. For the application of the system to the inspection and repair work in the car depot, there must be further improvement in its reliability. Furthermore there are plans for the review of such software features as the following:

(I) How to utilize the measurement data, and what the inspection and repair system should be?

(II) What the information control for data interchange between car depots should be?

Table 1 Functions and principle of operation of measuring devices

Name of device	Functions	Principles of operation
Device for detection of wear of pantograph pan	Automatic measurement of pantograph pan thickness with a precision of 0.5 mm when car enters or leaves inspection and repair shop	Moiré camera converts the state of wear of pan (slide plate) into moiré patterns, which in turn are converted into electric signals by means of pickup tube. By duly processing the amplitude, intervals and total number of the signals, the quantity of wear is calculated. To permit measurement even at car speed of 25 to 30 km/h, improvement is now under way for a device using a laser light source and a digital diode array.
Device for measurement push-up pressure of pantograph	Automatic measurement of pantograph push-up pressure against trolley wire with a precision of 0.3 kg when car enters or leaves inspection and repair shop	Optically detects vertical displacements of trolley wire stretched out at given tension, and calculates pantograph push-up pressure from these displacements.
Device for detection of wear of wheel flanges	Automatic measurement of cross-sectional profile of wheel flange when car enters or leaves inspection and repair shop	Irradiates parallel beam on exterior face of wheel from light source situated by the track. Irradiated light spot travels from top of flange to wheel tread as wheel moves on. By receiving the reflection by means of a pickup tube, the cross-sectional profile is illustrated.
Device for measurement of wheel back gauge	Automatic measurement of wheel back gauge when car enters or leaves inspection and repair shop	By means of gap sensors installed inside the track at a given distance, detects the change in inductance due to eddy current produced on inside of wheel and converts the distance between inside of wheel and sensor into electric signals, and thus calculates back gauge.
Device for measurement of wheel diameter	Automatic measurement of wheel diameter	3 differential transformers installed longitudinally along rail calculate wheel diameter by potential difference among transformers as wheel moves by them.
Device for detection of abnormal vibrations in wheels	Detection at wayside of a truck differing in vibrating pattern from other trucks of a multiple unit while car is in motion	Measures vibrating condition of each truck at time of passing through the device by means of vibration acceleration meter placed on railroad tie (sleeper).

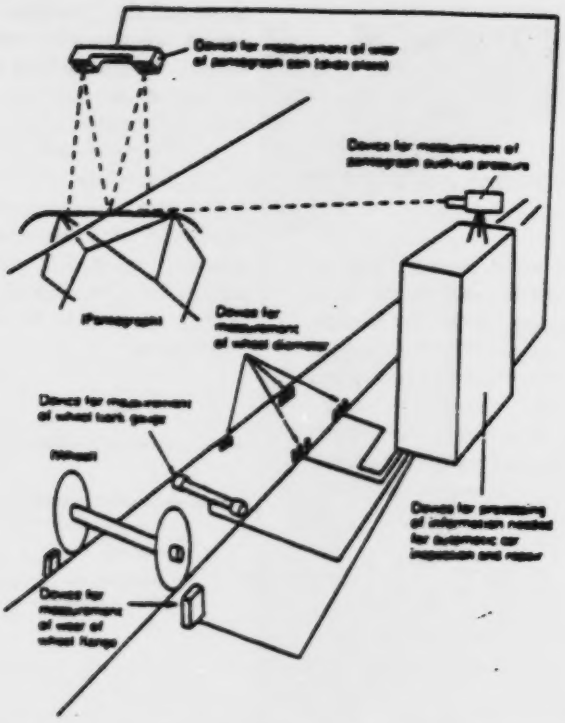


Fig. 1 Schematic illustration of automatic pantograph and wheel measuring system arrangement

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Device for Automatic Detection of Wear on Wheel Flanges

Kakutaro WADA*, Akio SHIOYA*

1. Introduction

Wear on the perimeter of a wheel increases with an increase in running distance. However, wear on the flange does not depend only on the running distance but strongly on the train's running route. Excessive wear or tangential wear on the wheel flange may lead to unsafe running and derailment. Therefore, it is better to inspect a wheel's perimeter in a shorter inspection cycle than of the car body inspection. However, it is necessary to concentrate manual labor in a time limit. Therefore, an inspection system has been developed to raise detection work efficiency by automatically operating.

2. Method for Measurement

This detection equipment having the measuring sensor fixed close to the rail at the entrance of a rolling stock shed can measure the profile of the wheel's perimeter without coming in contact with the rolling stock, as the train enters or leaves the shed.

A plane figure of this sensor arrangement is shown in Fig. 1. When each light beam is projected vertically on the left and right sides of the rail by the projector, it is shaded as a wheel goes into place, a light spot appearing on the wheel's surfaces. By turning of the wheel, the light reflection moves from flange to tread and further to the outside of the wheel.

Namely, a wheel is sectioned by the light beam. As a matter of fact, the light beam is projected at approximately 20 mm height above the rail head. On the other hand, the reflection seen from the running direction corresponds to the wheel shape and moves toward the direction of width keeping a fixed height constant. Instead of directly seeing the shape to be inspected, a video camera is set with the focus adjusted to the position of the light reflection. When the video camera is used for a horizontal and periodic line-scanning on the photoelectric plane, an electric signal sampling the continuously moving light reflection is obtained. This signal is counted as the time signal from the standard point of distance base. The section of the wheel's perimeter that is a locus of light could be obtained by restoring the moment changes of the time signal, although the original locus should be corrected on the section of radial direction as its flange portion has an elongated shape. Further, as the wheels to be measured have different radii, those of the wheels for Shinkansen and for conventional lines are respectively averaged.

* Control Engineering Laboratory

3. Trial Equipment

The trial equipment, by the measuring method in [illegible] above and Fig. 1, measures and processes both right and [illegible] wheels simultaneously while the train is moving. As [illegible] output, the cross-section of the wheels' perimeters [illegible] by the plotter and the measured data are typew[illegible]. Main performances of this equipment are as follows:

(1) The measurable train speed is 1~32 km/h;

(2) The video camera builds in the image detect[illegible] R 571 with the horizontal sweep frequency (line-scann[illegible] frequency) of 2 kHz, counting clock of 2 MHz, counti[illegible] accuracy being 0.25 mm/count. The signal proces[illegible] section has a memory capacity of 16 kW, and in case t[illegible] number of data is 80 per wheel, it has a capacity f[illegible] 140 wheels.

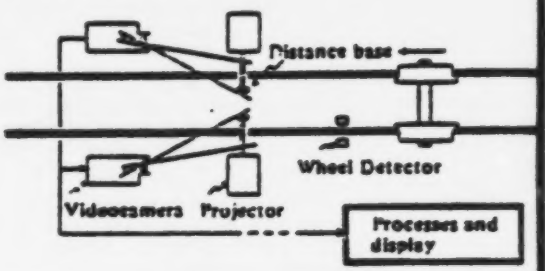


Fig. 1 Blockdiagram of the device

4. The Test Results in the Institute

Fig. 2 shows a right wheel profile output by the equi[illegible] ment when a piece of a wheel is placed on a moving tab[illegible] which is movable by 5 m and moves at 2 km/h. As the li[illegible] is projected from both outside of rails, only the light[illegible] portion is drawn. The ordinate shows the length of [illegible] radial direction, while the abscissa shows the direction [illegible] the wheel width. Although at present the trial equipme[illegible] only profiles the all measured wheel flanges, it is schedul[illegible] to add a function to judge if the thickness of flange, heig[illegible] shape of wear, etc. are within allowable scope.

(Pre. Report No. 1005, 197[illegible]

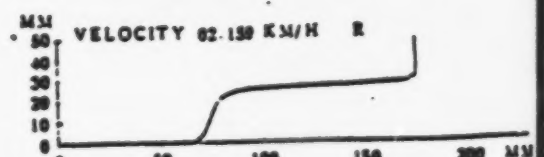
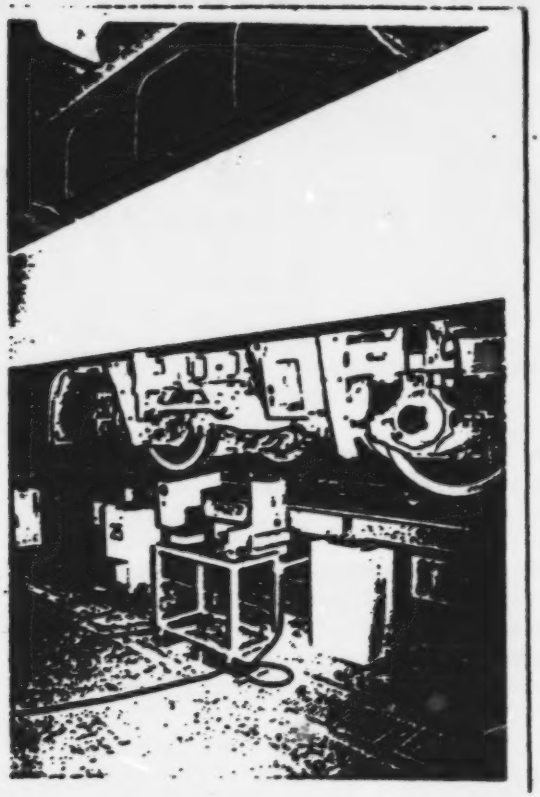
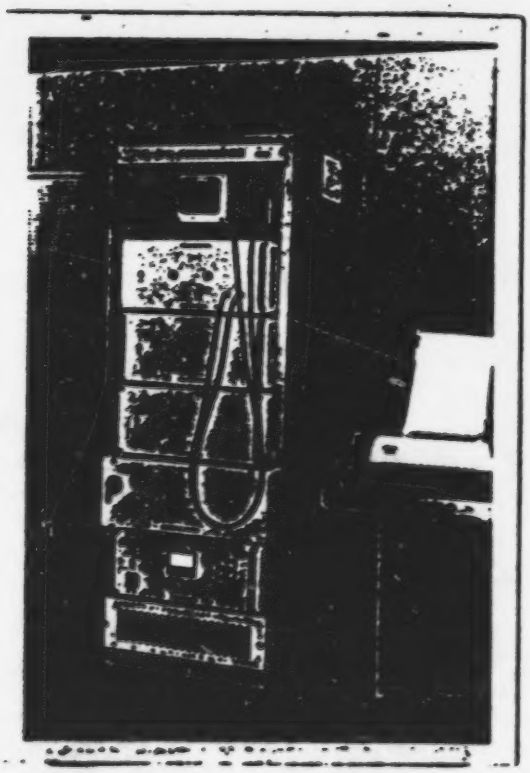


Fig. 2 Example of the wheel's perimeter drawn by X-Y plotter





Device for Automatic Detection of Wheel-Flat

昭和36年1月30日・第3種郵便物認可・鉄道技術　第294号・昭和57年6月1日発行(毎月1回1日発行)

トピックス

For Shinkansen
鉄道車両における車軸フラット検出装置の開発

日本国有鉄道・鉄道技術研究所

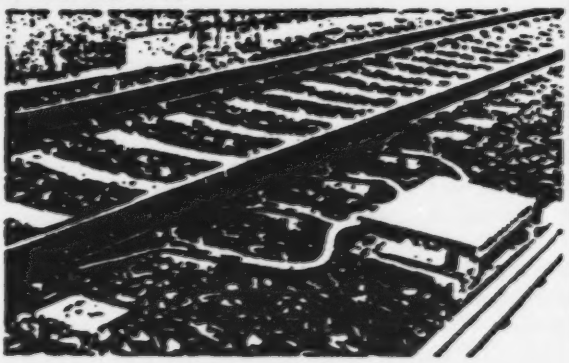
日本国有鉄道鉄道技術研究所自動制御研究室では車軸フラット検出装置を開発し，このたび東北新幹線の仙台車両基地に設置し実用化した。

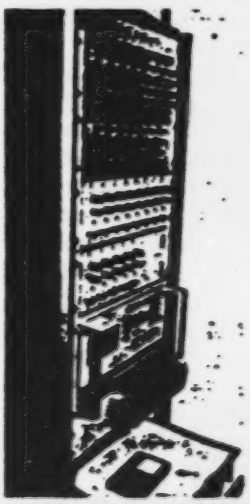
車両の高速運転に伴う増圧ブレーキの使用やＡＴＣ（自動列車制御装置：自動的に列車の運転制御を行う装置）の採用によって，車軸フラットの発生が大きな問題になっている。列車が走行中強いブレーキをかけられると，ブレーキ力によって車輪が回転を停止するためレール上を滑走して，踏面に一様摩耗して発生して行く円形状の平らな部分をフラットと呼んでいるが，このフラットが発生すると車軸の円滑な回転が妨げられるため，さらに滑走を誘発しやすくなりやがて車軸前面全周に多数発していく。このフラットによる繰返し衝撃が軌道や枕木をはじめ，車両自身や沿心地にも悪い影響を与え，騒音振動の原因にもなっている。

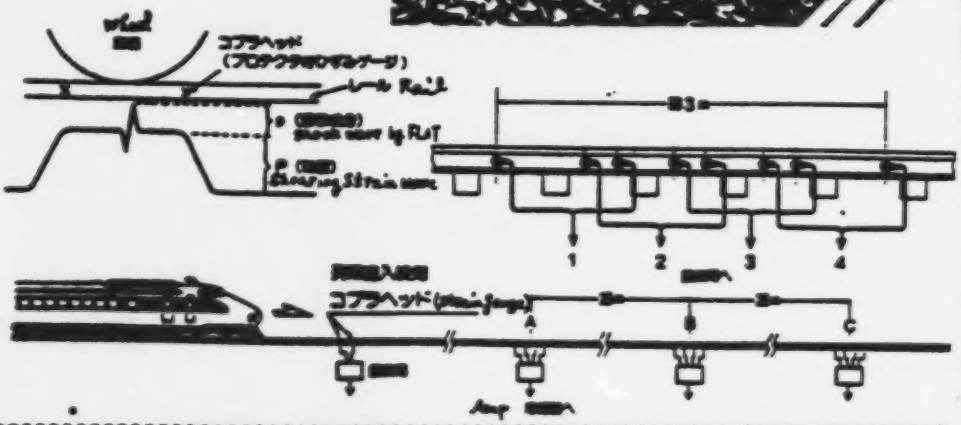
このたび開発した車軸フラット検出センサはレール腹部に剪断ひずみゲージ（コプラヘッドＦＣＨ－Ａ－３）を車軸一周区間に４組づつ約３mレールの中央部に取付け，これをレール３本に渡って設置した。このセンサ部を通過する車軸によるレールの剪断ひずみを増幅器（ＤＰＭ－３０５Ａ３）を通して計測することにより軸重を求める方式（当研究室により貨車重量通過時検測装置として全国の主要ヤードに13基実用化済み）を利用し，軸重波形と車軸フラットによる衝撃波形をローパスフィルタ（ＬＦ－１Ｅ）を通して分離し，軸重波形に重畳する衝撃成分からフラットの大小が判定でき，異状車軸を有する列車の指摘，さらに異常の度合も印字出力ができるようになっている。

なお本装置には，原波形が全て蓄積，記録されるようにデータレコーダ（ＲＴＰ－６００Ａ）と電磁オシログラフ（ＲＭＳ－１１ＰＰＴ）が用意され，データレコーダは列車進入と共に自動的にデータを収録するようになっている。

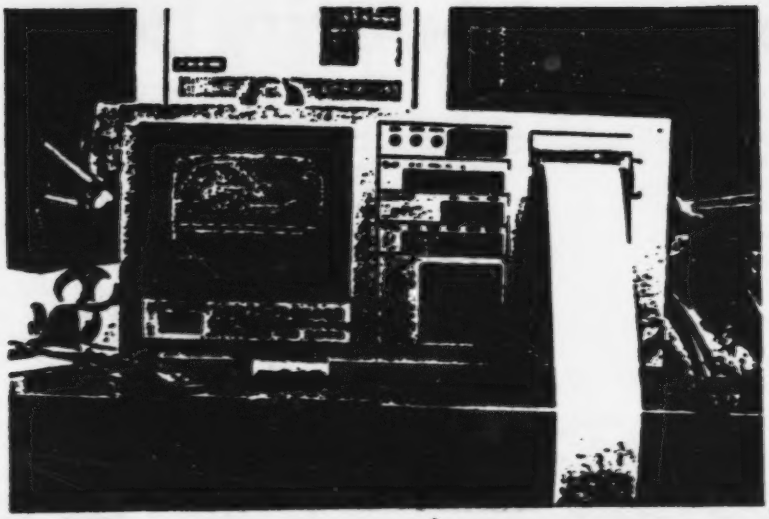
また上越新幹線新潟車両基地にも同装置が設置され，57年11月から可動の予定である。

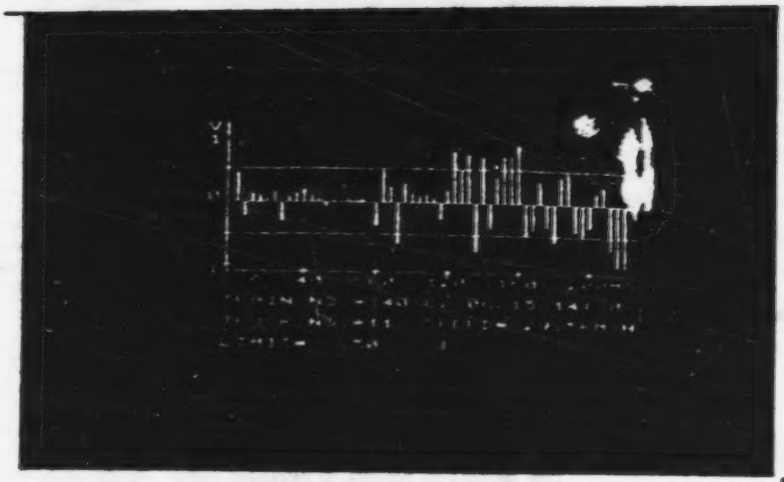




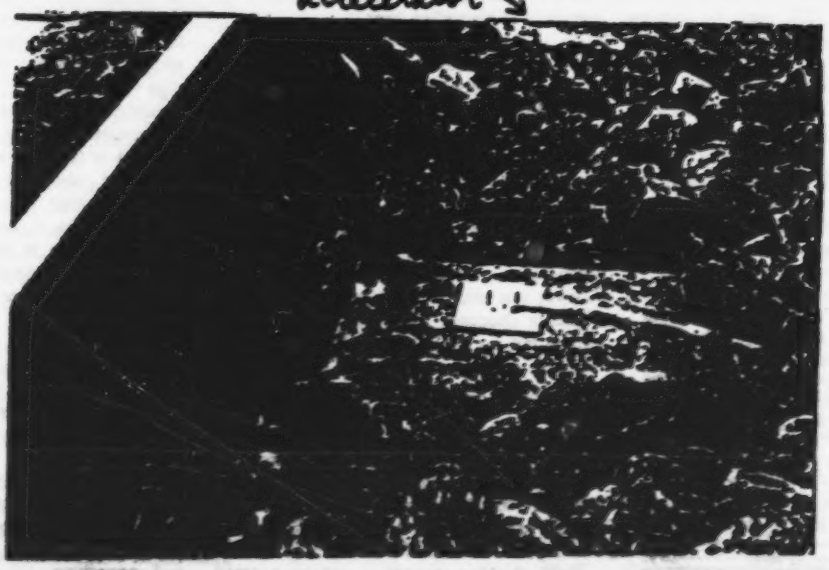


For Conventional line





accelerator ↘



Diversity brings success in the drive to cut energy costs

Dr-Eng Satoru Sone,
University of Tokyo

A wide variety of power electronics have been installed by JNR and Japan's many private commuter railways in their efforts to reduce electricity consumption. Where headways are close and stops frequent, expensive automatic variable-field choppers can boost regeneration to nearly 40 per cent of motoring energy. Future savings may come from such simple measures as reducing off-peak substation voltage, tailoring train formations to suit traffic, using microprocessors to optimise motoring-coasting-braking cycles, and streamlining; but new techniques like flywheel energy storage are still being explored

INTENSIVE UTILISATION, largely by passengers, gives Japan's complex network of public and private railways a head start in the race to cut energy consumption. The fact that Japan has to import most of the oil and coal she needs provides an added spur.

Fortunately, 54 per cent of Japan's 28 804 route-km of railway is already electrified (Table I). Although 65 per cent is single-track, the average density of passenger traffic is remarkably high at 30 700 passengers/day carried in 89 trains.

Another striking feature of Japan's railways is their diversity. More than 100 operators — from JNR with its 210 km/h shinkansen down to preserved steam railways — are continually experimenting and searching in co-operation with suppliers for greater energy efficiency.

While rail accounts for 40 per cent of passenger-km (JNR 25 per cent; private railways 15 per cent), buses carry 15 per cent and cars 40 per cent; the remaining 5 per cent go by air or sea. When energy consumption for passenger movement is examined, however, rail and cars account for 10 and 75 per cent respectively even though they are shifting the same volume of traffic.

Indeed, traffic density on Japan's railways is so high — and energy-saving policies so successful — that even when diesel traction is included, the trains are significantly more efficient than buses:

	kcal/passenger-km
Trains	102
Buses	156
Cars	716
Planes (domestic flights)	688

Mostly EMUs

Table I gives a breakdown of the total network as between JNR and the various private and independent railways (JPR).

So far as the private railways are concerned, almost all of the traffic is carried in some 18 000 electric multiple-unit cars of which 72 per cent are motored. Though less marked, the dominance of EMUs applies to JNR traffic also. In addition to 2 706 shinkansen cars (all motored), there are 15 900 EMU cars operating on JNR's 1 067 mm gauge network of which 59 per cent are motored.

Table I. Total route-km and proportion electrified for JNR and Japan's private railways at the end of 1982

	Route-km	Electrified
JNR shinkansen	1 959	100%
JNR other lines	21 423	41%
Private railways	4 811	39%
Tramways	208	100%
Metros	202	100%
Funicular rail	46	100%
Monorails	27	100%
Total	28 804	54%

Table II. Number of cars and car types (in italics) including trailers delivered to Japanese railways for use on dc lines in the 12 months ending March 31 1982

	Rheostatic	Field chopper	Armature chopper	JNR	JPR	Totals
Body construction:						
carbon steel	891	381	210.2	684	278	962
stainless steel	12	68	70.2	150	100	250
aluminium alloy	47	28	112.8	140	48	188
JNR	829	0	280	1 109	0	1 109
JPR	120	477	102.2	699	399	1 098
Totals	949	477	382.2	1 808	399	2 207

* One type is a dual-system energy saver

With a total of almost 25 000 motored EMU cars operating in the country, and the EMU fleet carrying 90 per cent of passenger traffic on rail, there is a powerful incentive to innovate and improve efficiency among the 70 operators of electrified lines.

Early into choppers

This explains why Japan was early into the field with choppers. As Table II shows, the earliest is substantial with some 1 300 cars for use on dc lines delivered in the year ended March 31, 1982.

In 1968, the Tokyu Electric Railway introduced Series 8000 with 130 kW compound motors and field choppers giving regenerative braking. Hanshin Electric Railway was next with Series 7000 which has armature choppers supplying 110 kW series motors but no regenerative braking. In 1971 Toto Rapid Transit Authority had its Series 6000 cars in service with armature choppers supplying 145 kW series motors and regenerative brakes.

While the Tokyu and Toto cars were used for services with frequent stops, the Hanshin cars were for limited-stop or express service which explains the lack of regenerative braking.

Field chopper control — where a small powered (typically 1 500 V 50 A) single-phase chopper regulates series-connected separate fields with the armature and series field rheostatically controlled — proved so successful as regards low cost and high energy saving due to regenerative braking that many railways have adopted or are considering this system for general use, other than in metro type operation.

Although the armature circuit is controlled rheostatically, energy consumption by the rheostat is far less than that of conventional rheostatic control, mainly because regenerative rather than dynamic braking is used but partly because a lower rated speed can be selected thanks to the wider range of field control. This reduces car weight by about 500 kg per power car which again contributes energy saving.

Armature chopper control, which facilitates regenerative braking down to a very low speed, was at first thought to be the best solution for dc traction. But experience revealed some important drawbacks:

- to achieve regenerative braking at relatively high speed, rated speed must be set higher than for rheostatically-controlled vehicles, which means higher power traction motors and converters;

Toito Rapid Transit Authority's aluminium-bodied Series 6000 EMUs, introduced in 1981, are among the most energy efficient suburban trains in Japan, using only 60 per cent of the energy needed by more conventional trainsets

- the weight, volume and cost of traction equipment is considerably greater than for field chopper/rheostatic control vehicles (because of very low price of camshaft controllers in Japan thanks to mass production, the much higher cost of armature choppers is not generally justified);
- the greater amplitude and shorter duration of peak power in motoring and regeneration produces larger losses in the supply network and a greater possibility of non-receptivity, thus requiring more substation capacity.

To overcome these drawbacks, ways of combining traction equipment ratings have been keenly sought. Various measures have been tested or used so far: series-parallel chopper, use of low-rated-voltage motor, several types of automatic field control, and combined rheostatic/regenerative control.

The most successful use of armature choppers is on metro cars which operate through on to suburban lines, a common practice in Japanese cities. In urban areas where the distance between stations is short and mostly underground, regenerative braking is very efficient. Most metro cars designed since 1970 are therefore armature chopper controlled.

Other than metro cars and various prototypes, there are only two production types of armature chopper controlled EMUs: Hanshin Electric Railway's Series 5000 used exclusively on services with slightly less than 1 km between stops, and JNR's Series 201 general purpose trainset. To obtain high braking performance, Series 201 connects a braking rheostat in series with traction motors when speed exceeds 75 km/h. Typical performance characteristics of armature chopper cars are set out in Table III.

Line receptivity

Energy savings from regeneration are very sensitive to train headways and running time between stations, which suggests dependence on receptivity of the line. This knowledge led to a very fruitful experiment.

All armature chopper controlled trainsets have two threshold values V_1 and V_2 to avoid line overvoltage. V_1 is the value over which maximum braking current regenerated is reduced, and it is completely pinched off at V_2.

Experiments have demonstrated that the regeneration ratio increases sharply as these voltage threshold values rise. Whereas regenerated energy was as much as 27 per cent of the total energy supplied with V_1 set at 1 730 V (nominal 1 500 V) using JNR's Series 201 prototype, the proportion dropped to 16 per cent when V_1 was reduced to 1 650 V, with a marked rise in brakeshoe wear.

The latest principle is that V_1 and V_2 should be set as high as possible, although some allowance in $V^2 - V^1$ is necessary for stability and small transient overshoot, and for smooth blending in of mechanical braking.

To improve matters further, I am proposing a reduction in substation voltage in off-peak periods from 110 per cent down to 100 or perhaps 105 per cent of nominal voltage, which should save at least 2 per cent of energy with no possibility of delays to trains.

The effect of armature chopper control was investigated and analysed in detail by Mr T Kono of TRTA using the data obtained from Series 6000 chopper and Series 5000 conventional cars. His more important results are set out in Table IV. Note, however, that the mass reduction from 436 to 399 tonnes are due to the use of light alloy bodies accounts for 18 per cent of the energy saving.

As shown in Fig 1, Series 6000 is much inferior to Series 8000 when braking regeneratively in the high speed region.

Recent trainsets using automatic variable-field choppers (or similar measures for expansion of the effective regenerative region) regenerate more energy than Series 6000, and net energy consumption — excluding the effect of lightweight bodies — is estimated to be slightly over 60 per cent of that for a rheostatic controlled car without regeneration in metro operation.

From this figure, armature chopper control is justifiable economically even in Japan where the price differential between chopper and camshaft control is most unfavourable.

Estimated energy savings of 25 to 30 per cent for suburban use — let alone the 20 per cent achieved by inter-city services — do not justify the adoption of this expensive chopper, since the alternative field chopper shows very similar energy-saving figures. This is the reason why JNR, having stuck to series-wound motors per control circuit from 4 to 8 or 12, as is the case with Series 800 cars of the Keihin Express Electric Railway;

To improve the energy saving achieved through field chopper control, three measures have been adopted by Japanese railways:

- an increase in motored axles, achieved economically by increasing number of traction motors per control circuit from 4 to 8 or 12 as is the case with Series 800 cars of the Keihin Express Electric Railway;
- priority for regenerative braking, the mechanical brake on trailer cars not being used except in emergency or at very low speeds;

Table III. Typical armature chopper controlled trainsets used in Japan

Series	TRTA 6000	JNR 201	TRTA 8000	JNR 203
Standard formation	6M4T	6M4T	6M4T	6M4T
Type of train	metro/ suburban	suburban	metro/ suburban	metro/ suburban
Train length	200 m	200 m	200 m	200 m
Body material	aluminium	carbon steel	aluminium	aluminium
Tare weight tonnes	282	376	303	312
Maximum load tonnes	200	200	200	200
One-hour rating:				
output kW	3×1 180	3×1 200	3×1 280	3×1 200
at speed km/h	54	82	49	46
Acceleration m/s^2	0·92	0·69	0·82	0·82
Deceleration m/s^2	1·03	0·97	0·97	0·97
Maximum speed km/h	100	100	100	100
Chopper type	basic	basic	automatic variable field	basic
Method of high speed regeneration	high rated speed	weak-field and series resistor	automatic variable field	series resistor
Thyristor rating	1 300 V 400 A	2 800 V 400 A	2 800 V 1 000A	2 800 V 1 000 A
Cooling	forced air	forced air	freon	forced air
Traction motor	dc series	dc series	dc split field	dc series
First year of operation	1971	1979	1981	1982

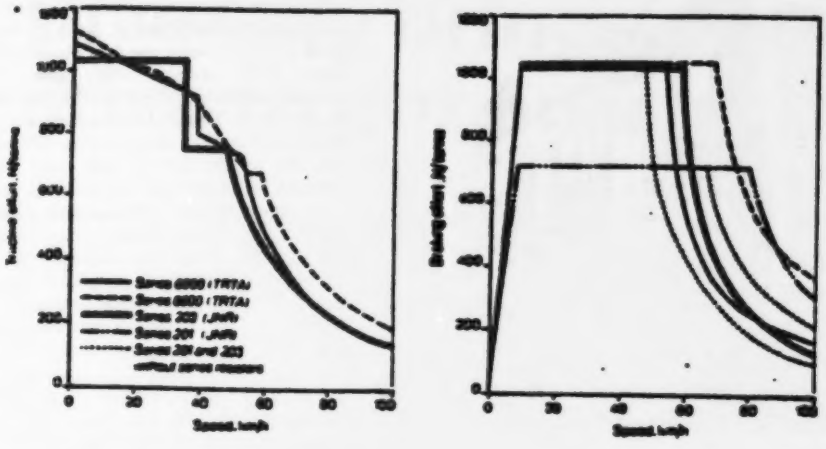


Fig 1: Comparison of power and braking rates for recent Japanese armature chopper controlled EMUs

• parallel-to-series switching of the regenerative brake so as to extend regeneration to a lower speed.

One disappointment encountered in the early days of choppers was the need for frequent maintenance of chopper cooling systems. This problem was solved by freon cooling, thus dispensing with fans and air inlet filters.

Induction motors

Although there is at present only one type of inverter-fed three-phase induction motor EMU (Series 8200 of Kumamoto City Transport Bureau) actually used in revenue earning operation in Japan, most leading manufacturers have not only completed detailed designs, but also made and tested a prototype car if not a complete set of equipment.

As compared with the armature chopper, inverter equipment is about 10 per cent smaller in volume and weight for the same output, while the weight of the traction motor is considerably reduced from 4·7 to 3·5 kg/kW in the 150 kW range with maximum allowable speed increased from 4 500 to 6 000 rev/min. Efficiency is a little worse, down from 92 to 90 per cent.

A valuable advantage is that the available adhesion coefficient will be lifted from 16 to 17 per cent up to 20 to 25 per cent due to parallel connection and the flat speed characteristics of three-phase traction motors.

If this improvement is exploited by reducing the number of motor cars from six to five for a 10-car trainset in metro service, net energy consumption is estimated to be 90 per cent of that for a dc chopper train with 1·2 km station spacing and a scheduled speed of 32 km/h inclusive of stops.

Locomotives

Two types of electric locomotive with independent choppers for the armature circuit and field circuit of each traction motor were built by Japanese companies in 1981. Type EF67 of JNR is a 2 850 kW Co-Co banking locomotive for use on a section of 2·3 per cent ruling gradient. Though the main purpose of the chopper is to improve adhesion, it saves energy too because it replaces two old and heavy 1 350 kW 2Co+Co2 locomotives and uses regenerative braking on the return journey.

The other is a 1 550 kW monomotor bogie locomotive for Spanish National Railways, made by Mitsubishi. These Class 251 locomotives have dynamic braking instead of regeneration because the routes they are used on are not considered sufficiently receptive.

Although two types of ac locomotive equipped with regenerative drag braking have been successfully used since 1968 in a restricted area where long ruling gradients of up to 3·3 per cent exist, no regenerative brake has yet been used for stopping, mainly because of the increased psophometric current. A sophisticated reactance design with divided secondary windings in the main transformer was successful in reducing the injection of noise into the line, so an ac EMU with a regenerative brake used for stopping will be produced in a couple of years.

Increasing line receptivity

Where there is a long and steep gradient, especially in tunnel as is the case where the Kobe metro passes under a mountain range, it is worth installing an inverter at the substation; some of these inverters can be used as rectifiers if necessary.

In contrast, rubber-tyred vehicles with higher running resistance on level lines offer little scope for the inverters which have been installed in Sapporo's subway.

The temporary storage of surplus energy in a flywheel was developed by Mitsubishi and is being tested by Keihin Express Electric Railway (RG April 1982 page 291). A vertical-axis flywheel is coupled to a dc machine with separate excitation control.

The prototype flywheel can store 15 kWh by increasing speed from 800 to 1 600 rev/min. There are two proposed operating modes: energy storage and voltage drop compensation. In a favourable simulated example of power flow at a flywheel

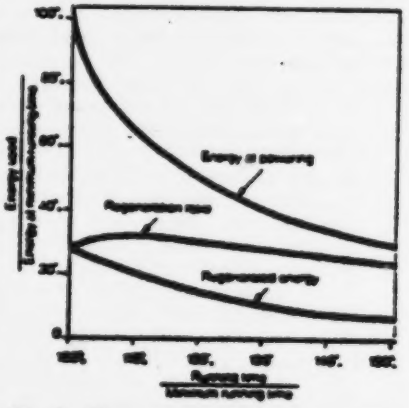


Fig 2. Characteristics of an armature chopper controlled vehicle with fixed acceleration and deceleration rates

substation, the energy storage device accepts 76 kWh in a 20 min cycle and resupplies 51 kWh; the rest is accounted for by losses in the dc machine, resisting loss and auxiliary power.

If substation flywheels are to be applied widely, it is essential to reduce these losses as well as the weight and volume of the machine.

Lightweight construction

Reducing the mass of a train is a very effective way to save energy. The weight of an ordinary 19·5 m long, 2·8 m wide EMU car body may typically be 9·7 tonnes for carbon

Table IV. Energy consumption of Series 8000 (thyristor-stainless steel) and Series 8080 (armature chopper, aluminium) cars of Taito Rapid Transit Authority, measured by on-board kWh meter

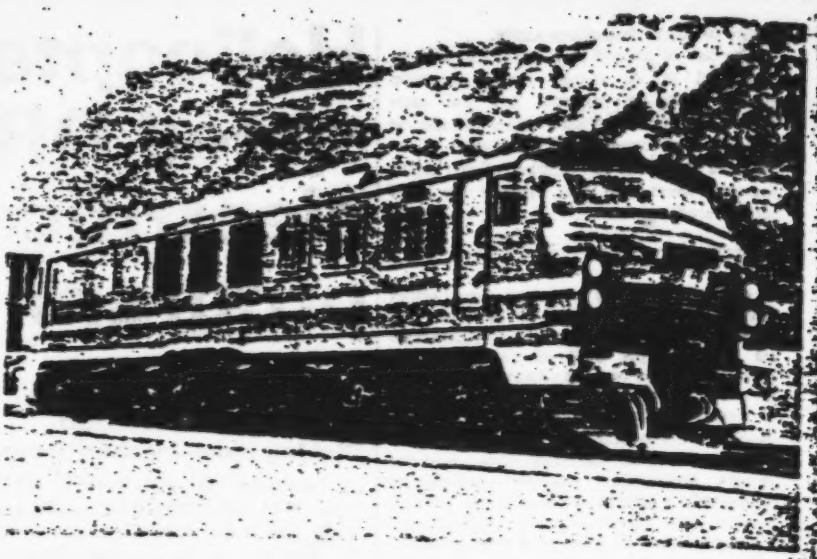
	Headway-min	Energy consumption kWh/car-km Series 8000 Power	Regen	Net	Series 8080 Power	Regen	Net	R/P	N/T
		P	R	N					
Early morning	11	1·88	0·88	1·40	2·08			28·2%	32·2%
Morning peak	3	3·48	0·88	2·61	3·48			27·6%	42·6%
Middle of day	6	2·23	0·88	1·67	2·60			29·6%	52·3%
Evening peak	8	2·43	0·77	1·68	2·68			31·7%	53·7%
Late evening	7	1·84	0·88	1·28	2·48			38·4%	47·6%
Midnight	11	1·81	0·48	1·38	2·42			25·6%	56·8%

steel, 5·8 tonnes for stainless steel and 4·4 tonnes for aluminium alloy.

Recent intensive study by Tokyu Electric Railway and Tokyu Car Corp using finite element analysis has made it possible to construct a 6·3 tonne stainless steel body of the required stiffness. Tokyu's Series 8090 trainset is the first product of this development. Elimination of weak points such as a door pocket corner where stress is concentrated, or revision of the specification itself (for example, maximum overloading or horizontal shock load at coupler) is being sought.

Several manufacturers have succeeded in developing bolsterless bogies for EMUs, the typical weight reduction achieved being 1·5 tonne/car.

Only recently has the equipment on an EMU been examined systematically from the viewpoint of weight reduction. The relative merits of concentration or distribution of motive power will be a keenly discussed issue in this connection.



Japanese-built Bo-Bo-Bo locomotives of Renfe Class 251 have field and armature choppers but do not have regenerative braking. Two of these locos were built in Japan; the rest are under construction in Spain using Japanese licences

Running resistance

Series 200 shinkansen trainsets used on the Tohoku and Joetsu shinkansen, both inaugurated in 1982, show much reduced energy consumption compared to Series 0 Tokaido and Sanyo shinkansen cars under similar operational conditions.

The saving has turned out to be as high as 30 per cent. The reasons — though not yet analysed in detail — are believed to be firstly the enclosed body skirts; secondly, forced-air cooling of traction motors instead of self-ventilation; and thirdly, the much stiffer concrete slab roadbed on which the trains run.

Measures now under consideration in relation to running resistance are:

- a reduction in the number of bogies through articulation — a test will be made by JNR using Odakyu Electric Railway's Series 7000 11-body 12-bogies trainset;
- use of the cross-anchor self-steering bogie;
- small cross-section high speed trains.

For each type of motive power, energy consumption has been analysed in detail against possible modes of operation. Normalised typical characteristics of basic armature chopper controlled vehicles, for example, are shown in Fig 2 where the operating mode is simply powering-coasting-braking with fixed acceleration and deceleration.

At minimum running time, corresponding to no coasting at all, energy consumption at powering is very high but regenerated energy is not so great. Scheduled running time should therefore be around 110 per cent of minimum running time.

Intermittent powering

For trains of medium speed running longer distances between stops, the difference in energy consumption between intermittent and constant-speed powering at the same average speed is slight. But if scheduled speed is close to maximum speed, intermittent powering means a lower average speed that requires less coasting and application of the brakes later at higher speed in order to achieve the same journey time.

The speed at which brakes are applied has a marked effect on energy consumption for all types of motive power.

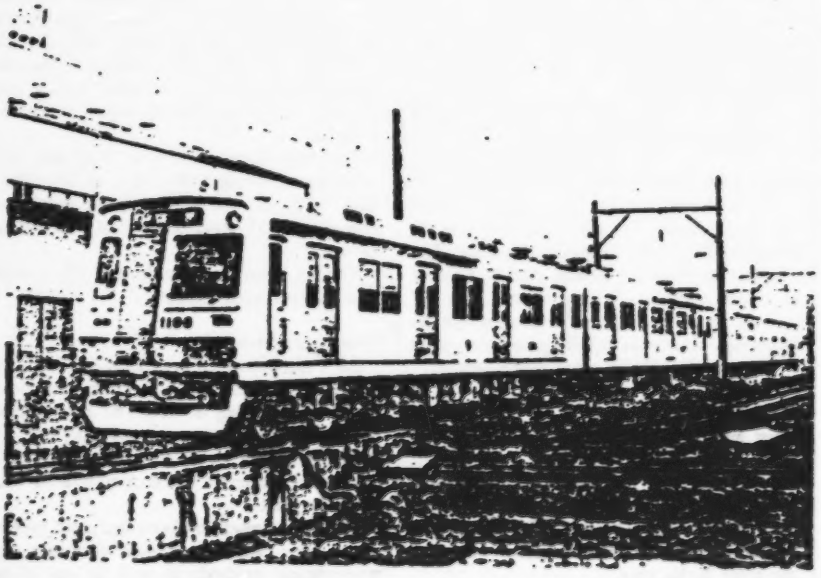
At high speeds, where running resistance increases sharply owing mainly to aerodynamic drag, the situation is not so simple. The two key figures — speed and the speed at which brakes are applied — should be set as low as possible to achieve a given running time, taking line profile and signalling conditions into consideration. Early attempts to do this by an on-board minicomputer will be recalled. These ideas will now be put into practice on the shinkansen, but using a much cheaper microcomputer.

Future measures

Various proposals for energy saving have been put forward for study or discussion: For example, lighter trains rather than lighter cars; train formation and/or headway could be adjusted more readily to traffic demand from the viewpoint of energy saving.

Fixed formations such as British Rail's HST, and fixed-interval timetables such as that introduced in Switzerland in 1982, have their attractions. But most of JNR's intercity trains are fixed formations running at fixed intervals, which is criticised as wasteful of energy.

One of the benefits of multiple-units is the



Kyoto City metro opened in May 1981: trains are formed of lightweight alloy-bodied chopper controlled EMUs. All axles are motored for high acceleration and regeneration

ability to adjust formations easily.

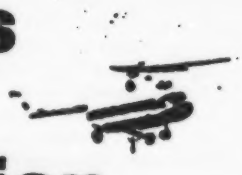
The use of limited stop trains can also be promoted as an energy saving measure. Station stopping patterns, and the combination of fast and slow trains should be carefully investigated. The Swiss Taktfahrplan in which the number of fast trains increased more than slow trains is worthy of further study. □

La diversité entraîne le succès dans l'effort destiné à réduire les coûts de l'énergie. Une grande variété dans l'électronique de puissance a été introduite par JNR et de nombreuses chemins de fer de banlieue Japonais privés dans les efforts qu'ils accomplissent en vue de réduire la consommation d'électricité. Lorsque les intervalles consécutifs sont rapprochés et les arrêts fréquents, des hacheurs coûteux à champ variable automatique peuvent renforcer la récupération à près de 40 pour cent de l'énergie motrice. Dans l'avenir, des économies peuvent fort bien provenir de mesures simples telles que la réduction de la tension hors-pointe des sous-stations, la composition des rames pour convenir au trafic, l'utilisation de micro-processeurs pour optimiser les cycles de marche sur l'erre et de freinage, ainsi que le carénage, mais de nouvelles techniques telles que la récupération de l'énergie par volant-moteur continuent toujours à être recherchées

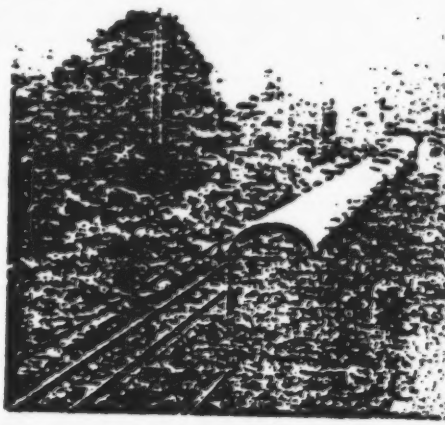
Vielfalt führt zum Erfolg der Bemühungen, die Energiekosten einzuschränken. JNR und viele der japanischen privaten Pendlerbahnen haben bei ihren Bemühungen, den Elektrizitätsverbrauch zu mindern, die verschiedensten electronischen Leistungsgeräte eingebaut. Wenn die Entfernung zwischen Stationen gering und ein häufiges Anhalten erforderlich ist, können kostspielige automatische Regelfeldzerhacker die Stromrückgewinnung auf nahezu 40 Prozent der zum Fahren verbrauchten Energie erhöhen. Verhältnismäßig einfache Maßnahmen wie z.B. das Reduzieren der Unterwerkspannung während Zeiten mit geringem Verkehr, die Zusammenstellung von Zügen entsprechend des Verkehrs, die Anwendung von Microprozessoren, um die Fahr-Auslroll-Bremsakte zu optimieren sowie Stromlinienge staltung können zu zukünftigen Einsparungen führen, dabei müssen neue Techniken, wie z.B. die Energiespeicherung im Schwungrad noch weiter erforscht werden

La diversidad contribuye al éxito de la campaña para reducir costes energéticos. Los JNR (ferrocarriles nacionales japoneses) y muchos ferrocarriles privados de cercanías del Japón han instalado equipo electrónico de corrientes fuertes para tratar de reducir el consumo de electricidad. Dondequiera que los intervalos entre trenes sean cortos y las paradas frecuentes, los costosos aceleradores de campo variable pueden aumentar la regeneración a casi el 40 por ciento de la energía de propulsión. Podrán lograrse otros ahorros en el futuro con sencillas medidas tales como reducción del voltaje fuera de horas punta en subestaciones, composición de trenes de conformidad con el tráfico, empleo de microprocesadores para optimizar los ciclos de la marcha (fases de propulsión, de motor sin consumo y frenos sin aplicar, y de frenado) y modernización, pero todavía se están explorando técnicas nuevas como el almacenamiento de energía en el volante

Helicopters speed DR electrification programme



Dipl-Ing Kurt Sobotta
Dipl-Ing Günter Ehrhardt
Dipl-Ing Hans-Joachim Krauss



By 1985 one-third of German State Railway's traffic will be handled by electric traction. As part of a nationwide programme being pushed through to reduce energy consumption, DR is electrifying 828 route-km in a four-year crash programme. DR engineers have developed novel techniques for catenary erection which include extensive use of prefabricated components. Helicopters are a novel way of positioning masts on busy lines

AFTER INDUSTRY and households, transport is the third largest consumer of energy in the German Democratic Republic. Diesel fuel alone accounts for about two-thirds of transport energy consumption.

National planning for the economy envisages that the cost of transport will be sharply reduced. This demands energy efficiency — a policy which favours rail and inland waterways at the expense of road and air.

DR has calculated that electric traction consumes three times less energy than diesel-powered trains. Electrification is therefore DR's most important tool in the drive to improve efficiency and reduce energy consumption.

Between 1981 and 1986 DR is electrifying 826 route-km at the standard system of 15 kV 16⅔ Hz, a target that was revised upwards last summer from 750 km. This is certain to help with the transfer of freight from road to rail as electrification raises route capacity by 8 to 12 per cent. At the same time, passenger journey times are reduced by 5 to 15 per cent depending on the characteristics of the route.

Another reason for electrification is that electricity can be furnished by burning lignite in power stations — lignite is one of the Democratic Republic's prime resources. Pollution-free operation of electric locos also favours their introduction — an important factor to remember as DR still has many steam locomotives in service.

Noise emission is also markedly lower than for diesel or steam locomotives.

Main lines go electric

The principal routes to be wired up by 1985 are from Halle, Leipzig and Dresden to Berlin, and from Berlin north to Rostock. The Magdeburg–Zielitz–Stendal line is another important artery in the programme.

In the first 18 months of the programme the following routes were wired up and energised:

- Elsterwerda–Berlin south ring–Seddin;
- Löcknewalde–Teltow.

They represent a total of 182 route km. On

May 23 last year the important marshalling yard at Seddin near Berlin was energised, and last month they were joined by the Seddin/Saarmund–Priort sections (44 km) of the outer Berlin ring.

During 1983 the western part of the outer Berlin ring will be wired, together with the first section of the Berlin–Rostock route as far as Löwenberg. Electrification will also be completed on the line running from the southern section of the outer Berlin ring through Berlin-Schönefeld airport to Berlin-Grünau.

Together these extensions will add 151 route-km to the electrified network. By 1985 a total of 2 500 route-km will be energised, representing 17·5 per cent of DR's 14 250 km network.

By then more than one-third of DR's traffic will be electrically hauled.

Work accelerated

DR's electrification programme places high demands on all the industries involved. Careful timetabling of work and co-operation between industrial partners are essential. To meet the targets set by the government, DR has had to accelerate the pace compared with previous years.

The rate of work has been increased several times over, demanding new planning and management methods as well as use of the

APPENDIX 12.1

SPECIFICATIONS FOR STEEL RAILS

(New Type Head-Hardened Rails)

MAY , 1981

FUKUYAMA WORKS

NIPPON KOKAN K.K.

Manager,
Rail and Shape Mill
Products Control

1. Scope

Specifications shall be in accordance with AREA (American Railway Engineering Association) specifications/1979 with the following modification and confirmation.

1.1 Section of rail is 136 lb/yd AREA specification.

1.2 Type of rail is New-type Head-Hardened (NHH).

2. Manufacture

2.1 The steel shall be made by a basic oxygen process.

2.2 The steel shall be cast by a fully killed ingot (with hot-topped) process or a continuous process.

2.3 Sufficient discard shall be taken from the bloom to insure freedom from injurious segregation and pipe.

3. Chemical composition

3.1 The chemical composition of the rail steel shall be with in the following limits:

	Weight percent
Carbon	0.70 - 0.82
Manganese	0.75 - 1.05
Phosphorus	0.035 Max.
Sulfur	0.040 Max.
Silicon	0.10 - 0.35

3.2 Analysis for ingot process shall be in accordance with AREA specification/1979.

3.3 Analysis for continuous process shall be one ladle samples from each heat.

4. Mechanical properties after heat treated

4.1 Surface hardness HB : 341 — 388

4.2 Hardness test shall be conducted on the surface of each heat-treated rails by Shore Hardness Tester.
(Checking point : Both ends of rail head)

4.3 The hardness pattern shall conform to the following :

4.3.1 The rail hardened layer shall have a cross section such as a depth of 15mm or over at the top centre and of 10mm or

over on the top undersides.

4.3.2 The hardened layer shall have no part exceeding 410 Vickers Hardness.

4.3.3 The distribution of hardness shall be tapered toward the inside, no sharp drop or discontinuity in the hardness.

4.3.4 The hardness pattern test shall be conducted on test per unit per 1,000m length.

5. Section

5.1 The section of the rails shall conform to the design approved by the purchaser subject to the following tolerances on dimensions.

5.1.1	height of rail	$+0.8^{mm}$,	-0.4^{mm}
5.1.2	width of the rail head	$+1.0^{mm}$,	-1.0^{mm}
5.1.3	thickness of web	$+1.0^{mm}$,	-0.5^{mm}
5.1.4	width of base	$+1.2^{mm}$,	-1.2^{mm}

5.1.5 No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing templet may stand out not to exceed 1/16 in. laterally.

6. Branding and Stamping

6.1 Branding shall be rolled in raised characters on the side of the web of each a minimum of every 16 ft in accordance with the follow -ing requirements:

6.1.1 The data and order of arrangement of the branding shall be in accordance with the drawings approved by the purchaser. (weight, section, mill brand, year rolled, month rolled)

6.2 There shall be at least one hot stampings in low relief into the web of each rail, the stamping shall be totally legible.

6.2.1 The data and arrangement of the marking shall be in accord -ance with the drawings approved by the purchaser.

6.2.2 For ingot process, heat number, rail letter, ingot number and method of hydrogen elimination shall be hot stamped.

6.2.3 For continuous process, heat number, rail letter, bloom number, strand number and method of hydrogen elimination shall be hot stamped.

7. Hydrogen Elimination

7.1 The rail shall be free from shatter cracks.

7.2 The above shall be accomplished by the Vacuum Treated (VT) process.

8. Resistance to Impact

8.1 Rail produced by a continuous casting process is not subject to the requirement.

8.2 For a ingot process, Drop test shall be made in accordance with the AREA specification.

9 Interior Condition

Nick and Break test shall not be conducted only in process using the fully-killed hot-topped ingot making system or continuous casting system.

10 Surface Classification

10.1 Rails free from surface inperfections and flaws of all kinds shall be classified No.1 rails.

10.2 Rails which contain surface inperfections in such number or of such charactor as will not render them unfit for recognized uses shall be classified as No. 2 rails.

10.3 No.2 rails shall not be accepted.

11 Length

11.1 The standard length of rails shall be 39ft or 12m.

11.2 Up to 9 percent of the total tonnage accepted from each individual order will be accepted in shorter lengths varying by 1m from 11m to 8m.

11.3 A variation of 11mm from the specified length will be permitted.

12 Drilling

12.1 The drilling shall be made only for the rails specified by the purchaser.

12.2 The drilling shall be made in accordance with the AREA specifica -tion if required.

12.3 The drilled rails shall be bevelled in accordance with the drawings approved by the purchaser.

13. Workmanship

13.1 Rails shall be straightened cold in a press or roller machine to remove twists, waves and kinks until they meet the surface and line requirements specified, as determined by visual inspection.

13.2 When placed head up on a horizontal support, rails that have ends higher than the middle will be accepted, if they have a uniform surface upsweep, the maximum ordinate of which does not exceed 19 mm in 39 ft or 12 m.

13.3 The uniform surface upsweep at the rail ends shall not exceed a maximum ordinate of 0.63 mm in 3 ft and the 0.63 mm maximum ordinate shall not occur at a point closer than 18 in. from the rail end.

13.4 Surface downsweep and droop shall not be acceptable.

13.5 Deviation of the lateral (horizontal) line in either direction at the rail ends shall not exceed a maximum mid-ordinate of 0.76 mm in 3 ft using a straight edge.

13.6 When required, proof of compliance with 13.2 shall be determined by string (wire) lining, and a straightedge and taper gauge shall be used to determine rail end surface and line characteristics specified in 13.3, 13.4, and 13.5.

13.7 Rails shall be hot sawed, cold sawed, milled, abrasive wheel cut, or ground to length with a variation in end squareness of not more than 0.8 mm allowed. The method of end finishing rails shall be such that the rail end shall not be metallurgically or mechanically damaged.

14 Acceptance

14.1 To be accepted, the rails offered must fulfill all the requirements of these specifications.

14.2 A-rails shall be accepted only in process using the fully-killed hot-topped ingot making system or continuous casting system.

14.3 X-rails shall not be accepted.

14.4 Supplier shall submit the manufacturer's drawings (Section, Brand -ing and Stamping) for approval.

15 Markings

15.1 Heat-treated rails shall be marked by either a metal plate attached to the neutral axis, which gives the manufacturer, type of rails,

year and month heat-treated and heat-treatment number.
Heat treated rails shall be paint-marked in accordance with the purchaser's specification.

15.2 A-rails specified 14.2 shall be paint-marked same as 15.1.

15.3 Paint markings will appear on the top of the head at one end only, at least 3 ft. from the end.

16 Loading

16.1 The packing shall be sufficiently sturdy to ensure that the rails shall not be damaged on route or in the handling.

16.2 Bare in bundle of 3 pieces with 3 bands.
(Placed in alternative position-Rail head above and below.)

17 Inspection and Tests

17.1 Mill's inspection prior to shipment shall be final as to quality and quantity.

17.2 The inspection certificate shall be furnished in mill's standard format after shipment.

17.3 If required, purchaser or third party designated by purchaser shall be agreed to have access to the premise of mill during mill's inspection subject to mill's final confirmation.

18 Weighing

18.1 Theoritical weight of 67.56 kg/m be applied for determination of weight.

19 Delivery allowance

20 Guaratee

21 Other terms and conditions

21.1 Not stipulated in this specifications shall be discussed and decided thrqugh mutual agreement between purchaser and mill.

Supplementary requirements

1 Ultrasonic testing

1.1 The rail may be specified to be ultrasonically tested for internal imperfections and pipe by the manufacturer.

2 Magnaflux testing

2.1 Bath ends of all rails are checked by the magnaflux tester concerning to the heat cracks.

APPENDIX 12.2

Basic Properties of High Strength Rail Steels and New Rail Development

OCTOBER, 1982

YAWATA WORKS

Nippon Steel Corporation

Basic Properties of High Strength Rail Steels and New Rail Development

Hiroki Masumoto* Chikayuki Urashima*
Kazuo Sugino* Masayoshi Hattori*
Hideaki Kageyama* Takao Terada**
Shin-ich Nishida*

1. INTRODUCTION

The requirements imposed on railways are presently very severe partly because of hard competition with other means of transportation, and a further improvement in efficiency is expected. From the user's point of view, railway transportation efficiency can be improved from two aspects : speedier transport of a large number of passengers and more efficient mass transport of cargoes. In respect of speedier passenger transport, Japan's SHINKANSEN enjoys world-wide fame. In other countries, especially in Europe, endeavors are presently being made aiming at speedier passenger transport, and the British HST and the French TGV belong to such projects. Typical examples of mass cargo transport are seen in countries rich in natural resources, such as the USA, Canada, Brizil and Australia, where masses of ores and other resources are transported by rail.

Such higher railway efficiency has lead to increased axle load and tangential and impact forces acting on rails through wheels, thus generating a very severe environment for rails where rail failures are apt to occur due to wear and fatigue. Rail maintenance work and rail replacements have become more frequent, and rail service life has markedly been shortened. Therefore, high-quality rails capable of withstanding these severe conditions are much in demand.

To meet the above-mentioned wear resistance and failure resistance, measures, such as enlargement of the rail cross section, only are insufficient and it is necessary to improve the material for rail itself. For this reason, rail manufacturers are engaged in the development of new rails. Nippon Steel Corporation developed a new high-strength head-hardened rail (NHH rail) of fine pearlitic structure and is supplying this rail to railways.

Recently, rails have become more frequently welded upon laying. This is because, in addition to the ensuring of comfortableness, deterioration of rails and ballast due to impact upon passage of wheels is to be reduced. Therefore, besides the above-mentioned resistance to wear and failure among the necessary properties of rails, weldability is also required as an important basic characteristic. To meet these three basic charateristics, it is necessary to newly consider the metallurgical structure and composition of steel as the material for rail.

From this standpoint, NSC made an investigation to find an optimum structure and composition that meet wear resistance, failure resistance and weldability, and manufactured weldable high-strength steel rails on a trial basis based on the results of the investigation.

*Technical Department, **Plate and Shape Department
Yawata Works

2. Metallurgical Factors Governing Wear-Resistance of Rail Steel

2.1 Rail Wear

Wear of rail generally takes three forms. First is adhesive wear caused by wheels, second is plastic deformation of rail head by heavy axle load and this causes lateral spread of rail which is chipped off by wheel flange. Another type of wear of this category is fatigue, as schematically illustrated in Fig. 1 which generates surface cracks resulting in flaking or rolling.

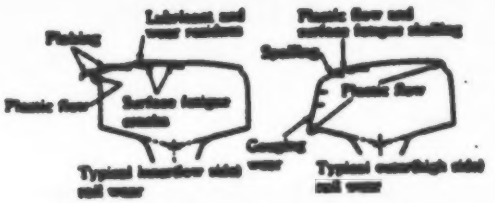


Fig. 1 Wear of rails in curves under heavy traffic conditions (J. Kalousek et al, 1978)

2.2 Experiment by Nishihara Type Wear Test Equipment

It is difficult, as described above, to fully simulate rail wear in the laboratory. We, therefore, adopted the Nishihara type wear test equipment to carry out comparative test for the wear on several rail steels with ordinary carbon rail steel as the control material. In the test, ring-shaped specimens were brought in to contact with standard mating specimen rotated 5×10^5 revolutions, and the weight loss of the specimens were measured and compared. The speed of rotation of the specimen cut out from the rail head was 800 r. p. m. and that of the mating specimen in contact was 728 r. p. m. Other test conditions are also given in Fig. 2

Shown in Table 1 are tested rail steels: ⓐ—ⓓ are of pearlitic structure differing in hardness, and ⓔ of tempered martensitic structure by heat-treating ordinary carbon rail steel. For comparison, it was tempered at two levels in hardness of about Hv 380 and 280. The specimen D was cut out of the newly developed rail head, and specimen E of Hv 380 was chosen as the mating specimen and used throughout the test.

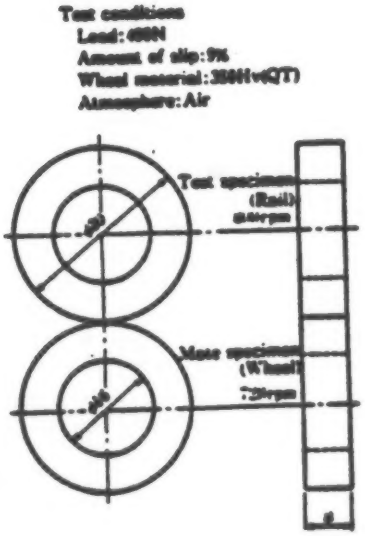


Fig. 2 Nishihara type wear test specimens and test conditions

The test results are plotted in Fig. 3 indicating good correlation between the amount of wear and hardness before test: the higher the hardness before test, the less the amount of wear. This agrees with a generally accepted view that the higher the strength of steel, the greater its wear resistance. The effect of microstructure on wear proves that the quenched and tempered martensitic structure suffered larger wear loss than the pearlitic structure at the same hardness level.

The surface hardness of specimens after wear test is in good correlation with the amount of wear, as shown in Fig. 4 indicating no difference between the pearlitic structure and the tempered martensitic one.

Table 1 Chemical compositions and mechanical properties of rail steels

	C	Si	Mn	P	S	Cr	V	PS (MPa)	TS (MPa)	El (%)	RA (%)	Hv
A Ordinary carbon rail steel (C)	0.65	0.20	0.89	0.019	0.009	-	-	482	904	14.5	19.0	254
B High Si rail steel (HS)	0.78	0.88	1.31	0.023	0.010	-	-	593	1,030	12.0	19.0	305
C Cr-V alloy rail steel (Cr-V)	0.74	0.32	1.32	0.028	0.012	0.78	0.13	755	1,178	14.3	19.1	347
D Head hardened rail steel (fine pearlitic structure) (HHF)	0.80	0.23	0.97	0.016	0.028	-	-	852	1,265	14.3	39.7	385
E Head hardened rail steel (tempered martensitic structure) (HH)*	0.66	0.24	0.73	0.020	0.015	-	-	1,030	1,208	16.4	48.3	350

* Used also for the material of mating specimen

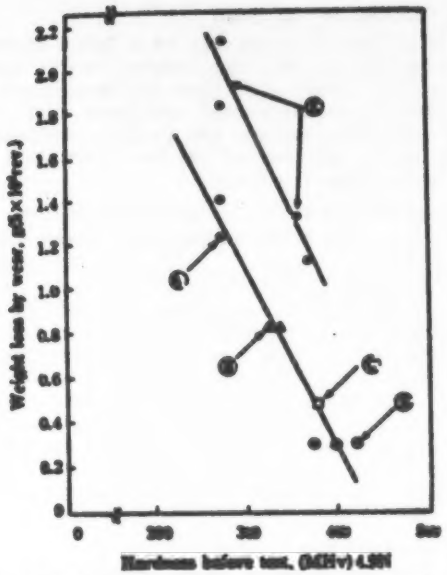


Fig. 3 Relation between hardness before test and amount of wear of various rail steels

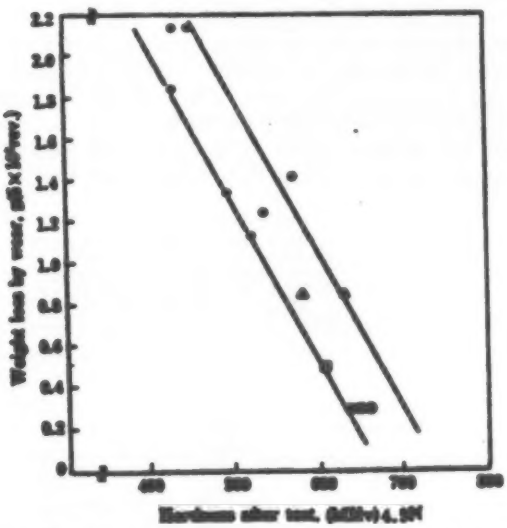


Fig. 4 Relation between surface hardness after test and amount of wear

Hardness difference between before and after wear test and the amount of wear are plotted in Fig. 5. It is clear from this figure that the hardness increase of the worn surface of the specimen of tempered martensitic structure is less than that of the pearlitic structure, and that the hardness increase is dependent only upon their microstructures and not the initial hardness. This fact points to the remarkable effect of the form of cementite carbide on wear of rail steel, and hence gives a valuable clue to wear mechanism.

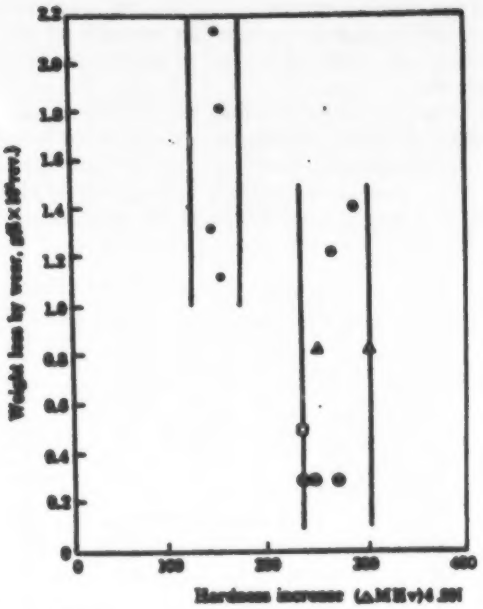


Fig. 5 Effect of microstructure on hardness increase after test

2.3 Wear Resistance of Rails in Service

The question, then, is whether the test results, discussed above, are in good agreement with the actual wear behavior of rails in service. Presented in Fig. 6 is the relation between the wear behavior data of several rail steels obtained over a long period of time on the rails of a mine railway and their results on corresponding wear tests. As far as the wear loss measured in two curved sections is concerned, both are in good correlation. Hence, the assessment based on the results of the wear test, discussed above, can be valid only if it is used for the qualitative analysis of rail wear and it can be concluded that in order to improve the wear-resistance of rail steels, their hardness or strength needs to be increased with pearlitic structure.

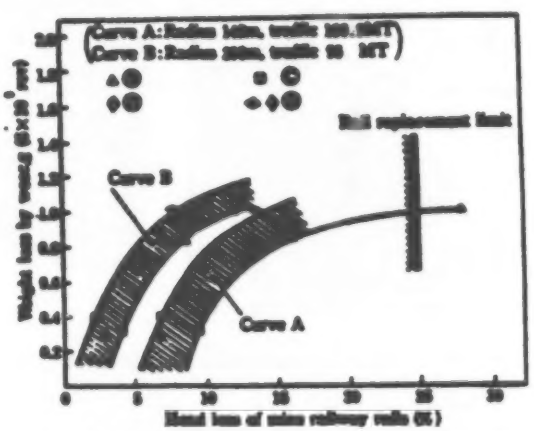


Fig. 6 Correlation between rail wear and wear test results

In this relation, as it was mentioned earlier that the toughness of rail head against plastic deformation is an important requirement for improving the wear resistance of rail, the attempt to increase the strength of rail steel is also in the right direction to effectively satisfy this requirement.

Fig. 7 shows, as an example, of plastic deformation of rail steels of varied strength levels as calculated from the data of an Australian mine railway. From this graph it is clear that as the strength of rail steel is increased, plastic deformation decreases in depth and amount in rail head.

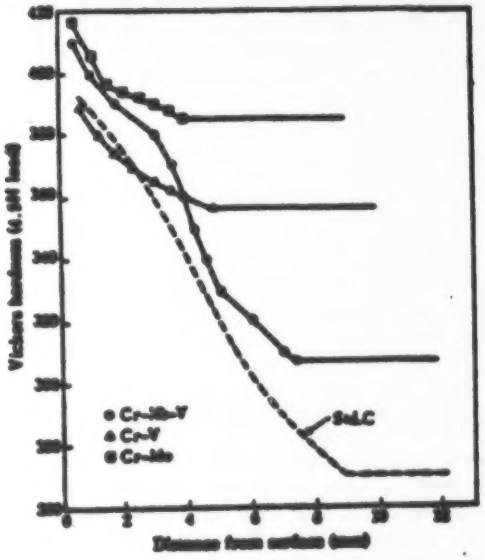


Fig. 7 Predicted hardness profiles in alloy rails after 189 MGT

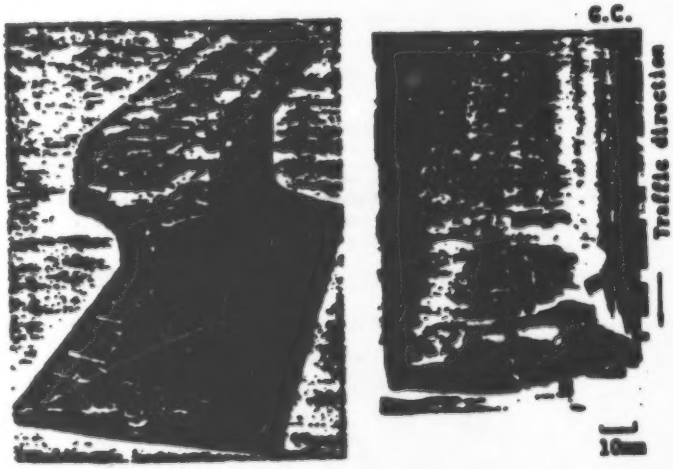


Photo 1 Rail failure from a dark spot (No.2212 rail)

3. Material Factors That Govern the Failure Resistance of Rail Steel

3.1 Failures of Rail Steel

Rail wear is predicted to a large extent and measures such as rail replacement can be taken according to plan, whereas fatigue failures occur abrupt and could cause unexpected accidents such as derailment. For this reason, the failure resistance of rails can be said one of the most important properties that rails should possess.

Among failures mentioned above the failures occurring to rail head due to the contact with wheels can be considered the most serious. Typical failures are head check and flaking occurring at the gauge corner of a rail, shelling and corrugation observed at the gauge corner and on the running surface of a rail. Many of these head failures still defy clarification of their causes and energetic studies are being made. A dark spot (or shelling on the running surface of rail) belongs to this category of failure. A dark spot observed on the running surface of a rail of a high-speed railway without heavy load was investigated and the following characteristics were revealed.

3.2 Characteristics of Dark Spot

The left photograph in Photo 1 shows rail failure from a dark spot on the high speed railway. Shown in the right photograph is a plan view of the same running surface of the rail. The main crack originates at the central part of running surface, which is shown at the central position in the photograph and runs 5~9 mm deep from the surface. A secondary crack propagating toward the base from the main crack reaches a fracture. The position at which this main crack was initiated is located on the running surface or in its neighborhood as can be confirmed from various observations, and the propagation

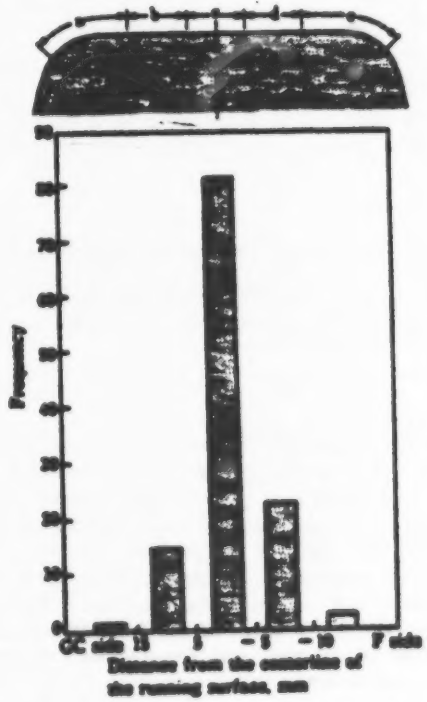


Fig. 8 Distribution of dark spots on the running surface of the rail

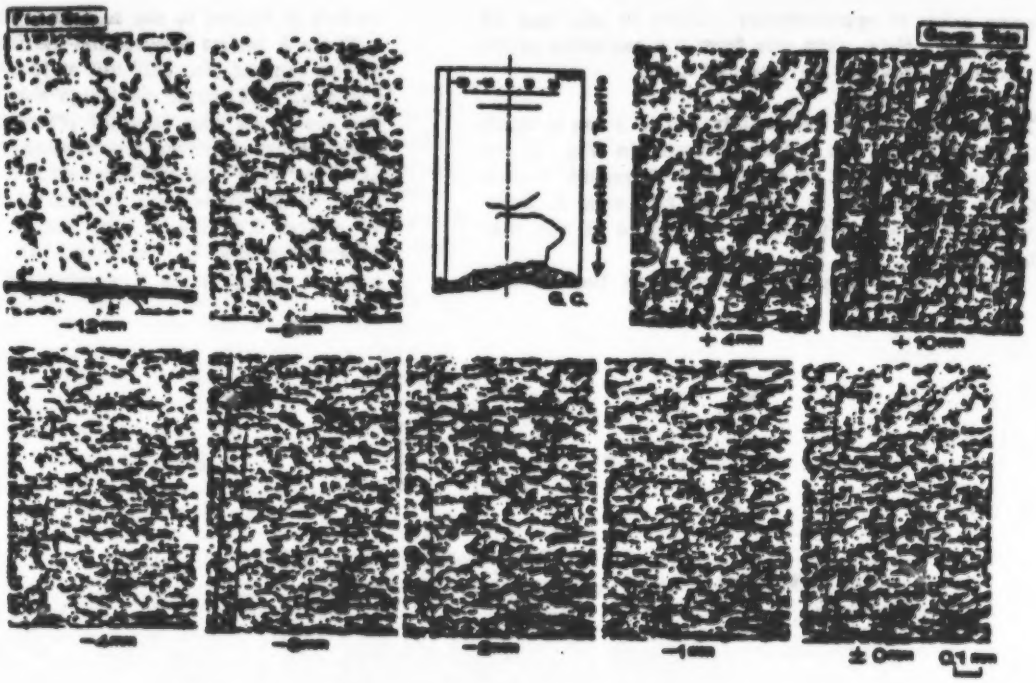


Photo 2 Plastic flow of the running surface (No. 2212 rail)

of this crack was, as can be partially seen in the photograph, caused by fatigue.

The appearance of the initiation and propagation of this crack is the same as that of flaking or pitting seen on rolling bearings, gears and rolling rolls, and therefore indicates that rolling contact fatigue causes such crack. Unfortunately because the crack initiating point on the running surface of the rail was later removed by passing wheels, further investigation became impossible. We, then, investigated the distribution of the dark spots on the running surface (such as shown in Photo 1) and found, as clear from Fig. 8, that most of them were concentrated within ±5 mm from the centerline on the running surface of the rail. Therefore metallurgical investigation of the failed rails was conducted through clarifying the microstructural change of this region to trace the cause of failure.

3.3 Analysis of Failed Rails

Among failed rails, Photo 1 shows a typical example of dark spot. The rail, No. 2212, installed in a tangent track sustained failure after the traffic reached approximately 200 million tons. Major observations of our study are as follows.

(1) The running surface of the rail is characterized by typical plastic deformation.

Photo 2 shows plastic flows observed on the running surface of No. 2212 rail. The plastic flows are very characteristic as they appear to be rotating round an axes perpendicular to the running surface. As is schematically illustrated in Fig. 9, no plastic flows heading in the traffic direction are observed, indicated by an arrow, near the central position of the running surface. Found in this region (called E region) are, however, tiny plastic flows running perpendicular to the traffic direction. The

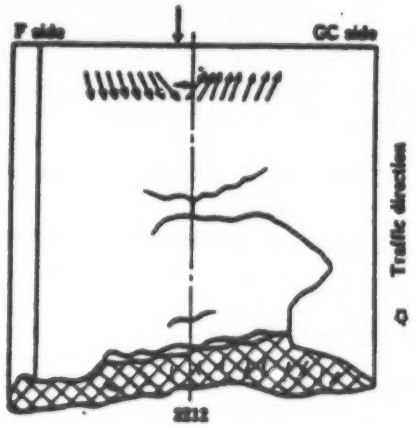


Fig. 9 Schematic representation of dark spot

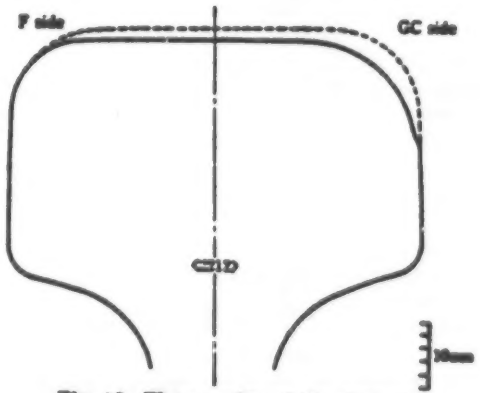


Fig. 10 Wear profile of No. 2212 rail

E region exists at approximately −2 mm in the case of No. 2212 rail. Here, gage side from the centerline of the rail surface is indicated by plus (+) figure.

(2) Wear loss is slight.

The wear loss of the rail is only 1.5 to 2 mm in depth on the centerline of the rail as indicated in Fig. 10 by profile compared to that of a new one. A general characteristic of No. 2212 rail is that gauge face wear is somewhat greater than that of the central region of the running surface.

(3) Plastic flows of the central region on the running surface is limited to the surface layer.

Photo 3 depicts longitudinal/vertical section (L section) of the head of No. 2212 rail at locations close to E region (±0 mm), +11 mm to the gauge side, and −20 mm to the field side. As was discussed previously, the plastic flow near central region on the running surface can be recognized as very slight as compared to those on both sides. Also, in the zones on both sides of E region the direction of plastic flow is reversed and it corresponds to the observation that microstructure on the running surface shows rotating plastic flow around the axis perpendicular

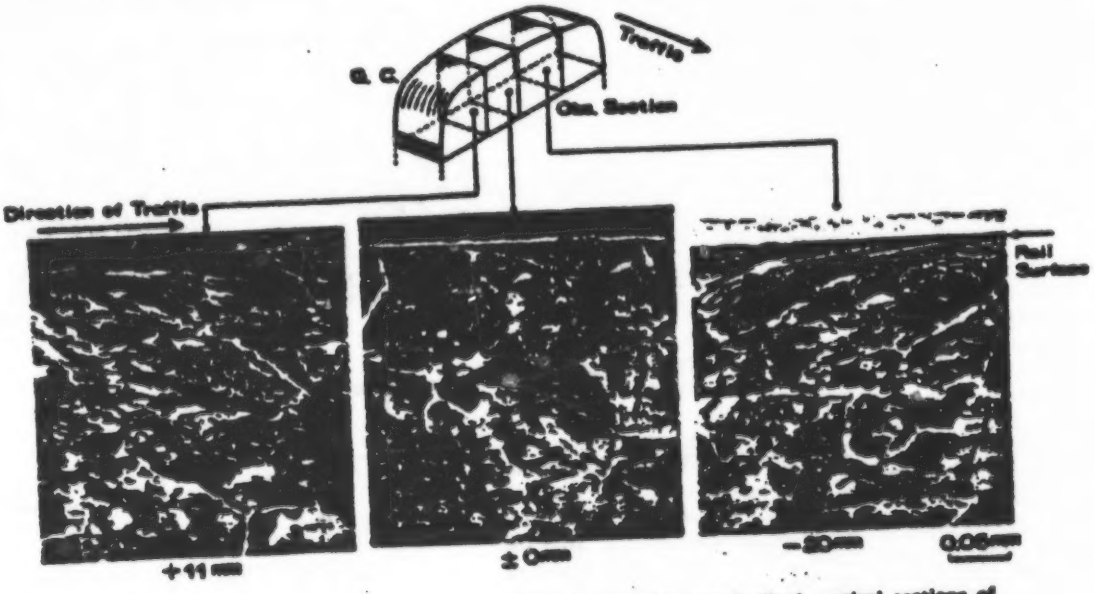


Photo 3 Optical micrographs showing plastic flow on the longitudinal vertical sections of No. 2212 rail

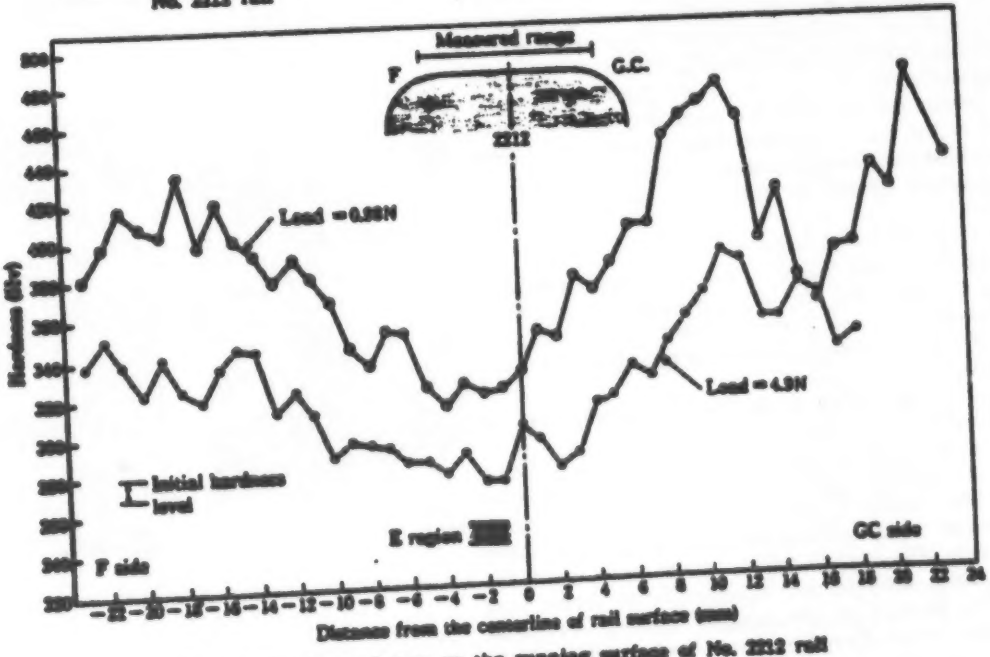


Fig. 11 Hardness change on the running surface of No. 2212 rail

to the surface. This can be explained by the fact that the rail surface receives from the wheel two kinds of tangential force, i. e., a small tangential force perpendicular to the traffic direction heading toward the gauge side and the force, which works parallel to the longitudinal direction, positive in the gauge side and negative in the field side.

(4) Hardness increase of the central region on the running surface is minimum.

Fig. 11 represents hardness change in the surface layer of No. 2212 rail. The hardness distribution curve lowest in E region and increases toward both sides, well corresponding to the changes of the plastic flow discussed earlier. Shown together in this figure are the measurements taken under a load condition of 4.9 N, indicating that the hardness values are approximately the same as the initial hardness value of base material. Comparison of these hardness changes with the frequency of failure in Fig. 8 reveals that the failures concentrate in E region where the deformation is least. In this sense, this type of failure is considered to be controlled by different failure mechanism and material properties from, for instance, those of head check occurring in the gauge face.

3.4 Test on Rolling Contact Fatigue of Rail Steels

From the observations discussed above, those which can be considered as relating to the failure mechanism can be listed as follows.

(1) The dark spot is a phenomenon due to rolling contact fatigue.

(2) The crack originates at the central region on the running surface of the rail.

(3) The amount of the wear loss on the running surface is slight.

(4) The central region on the running surface of the rail is deformed least showing the deformed surface layer of a few microns.

(5) The dark spot which was investigated in the present study has metallographically different characteristics from that of head check or other failure which occurs in the gauge face, for we have ascertained that the gauge face underwent the heaviest plastic deformation and hardness increase.

Based on these observations, it was considered that the study of the rolling contact fatigue characteristics of rail steel is especially important, and we adopted a new test method, the RCF test shown in Fig. 12. This method is an application of the conventional method adopted for testing bearing steel, etc., modifying Nishihara type wear test equipment. In the test by this method, a ring-shaped specimen is cut out of the head of rail steel and is tested with a mating ring specimen as a wheel in lubricated condition under a constant load and relative slip ratio of 20%. As the material for mating specimens ordinary carbon rail steel of tempered martensitic structure, Hv 350, was used in all experiments. The life of the rail specimen is determined by the r. p. m. at which contact fatigue failure occurs.

The same rail steels as those for wear testing were tested for their rolling contact fatigue characteristics by this method, and the test results processed according to Weibull distribution probability are shown in Fig. 13

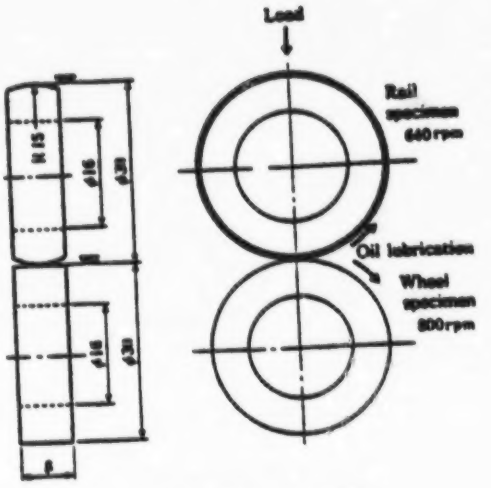


Fig. 12 RCF test method

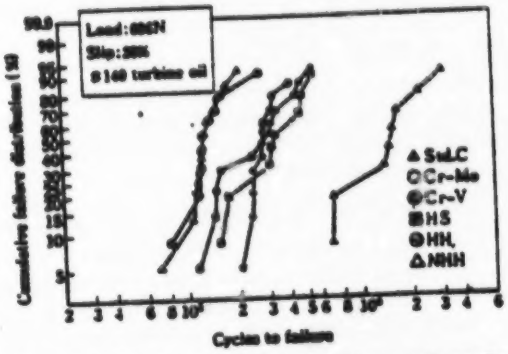


Fig. 13 RCF characteristics of various rail steels

They are:

(1) Rail steels tend to increase their life with higher strength.

(2) Increase of life cannot be expected of the rail steel of tempered martensitic structure (HH) despite its high strength.

(3) The life of a rail steel whose microstructure is changed to fine pearlite (NHH) by heat treatment is remarkably extended.

Thus, rail steels strengthened with fine pearlitic structure are not only wear-resistant but also effective against fatigue failures. As mentioned earlier, there are two processes for realising the fine pearlitic structure in rail steel. One is the heat treatment of rail head or all of rail and the other the addition of alloying elements, such as Cr, Si, Mo, etc.

What causes the difference in the effect of microstructures on the rolling contact fatigue characteristics of rail steels poses an interesting question. Fig. 14 indicates the change of the critical strain to failure when microstructure and strength of a rail steel are changed.

Obviously, pearlitic structure is superior to tempered

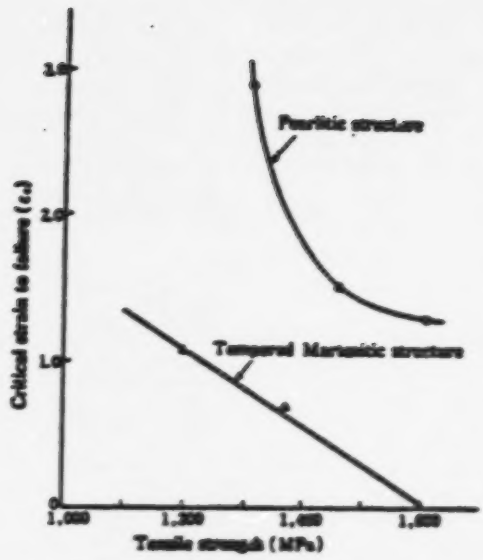


Fig. 14 Effect of microstructure and tensile strength on critical strain to failure

martensitic structure in its plasticity, though all strength levels. This difference is now regarded as one of the factors which govern the characteristics of rolling contact fatigue and study is under way.

4. Fatigue Characteristics of Rail Steels

4.1 Fatigue Strength of Rail Steels

The rail failure proceeds, as a matter of course, from the initiation of a crack to final brittle fracture as the crack propagates under a repeated load. In the foregoing section we dealt with the characteristics of rail steels from the viewpoint of rolling contact fatigue. This corresponds to a measure for resistance to crack initiation of rail steels. In this section the general fatigue properties of rail steels will be treated because the fatigue characteristics of rail steel hold an important bearing on the safety aspect as can be understood from the foregoing discussions.

Fatigue test was conducted by three test methods.

1) Three point bending fatigue test applied to an actual rail with its head subjected to tension
2) Rotating bending fatigue test applied to a specimen cut out of a rail head
3) Plane bending fatigue test applied to a specimen with as-hot-rolled surface on one side cut out of the top surface of rail head.

First, the results of three point bending fatigue test conducted on actual rails are plotted as a function of tensile strength in Fig. 15 In this respect, the heat-treated rail registered the best performance of all. This is due to large compressive residual stress in the outer layer of rail head. The performance of other types of rail steels is constant, unaffected either by steel grade or tensile strength.

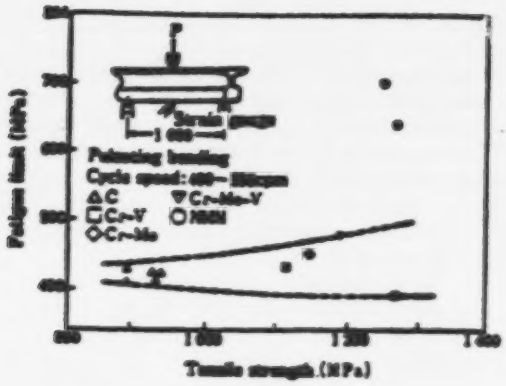


Fig. 15 Three point bending fatigue strength of actual rails

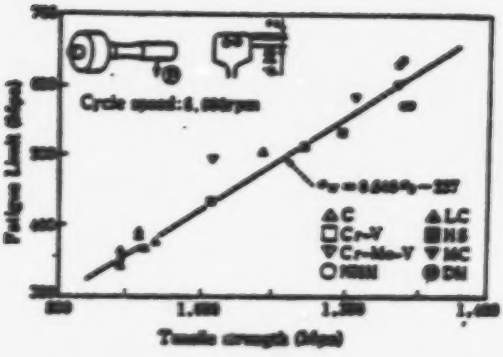


Fig. 16 Rotating bending fatigue strength of various rail steels

Secondly, the results of rotating bending fatigue te plotted against tensile strength are given in Fig. 16.

The rotating bending fatigue strength of various ra steels is in proportion to their tensile strength, and ca be approximated by the following equation.

$\sigma_w = 0.546\,\sigma_B - 227$ (MPa)

Thus, it is clear that even the rail steels have fatigu strength dependent on tensile strength, the same as genera structural steels.

Hence, because the results of the bending fatigue te of actual rails could have the combined effect of surfac property and residual stress, we took plane specimens having the hot-rolled surface of the rail head and conducted plane bending fatigue test. Shown in Fig. 17 are the tes results plotted, like in the previous figure, as a functio of tensile strength. As is clear from this figure, the ordinary carbon rail steel shows generally satisfactory performance among the rail steels except the heat-treated steel. The fatigue strength of alloy rail steels which have high static strength is slightly lower than that of the ordinary carbon steel. Although heat-treated rail steel is affected considerably by residual stress, it still retains high strength. The reason for this has not yet been clarified though some can be postulated. In any the surface property of actual rai is one of the imp

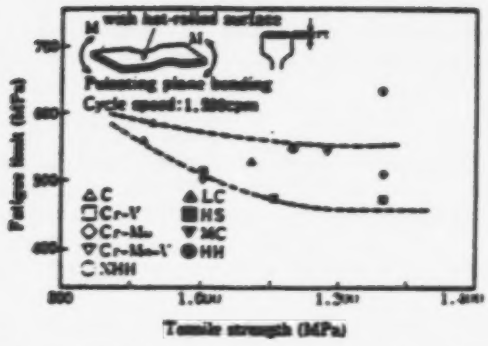


Fig. 17 Plane bending fatigue strength of specimens cut out from the rail head with as-hot-rolled surface

factors which determines rail fatigue strength.

4.2 Residual Stress of Rail Steels

As it was clear from the observation, in the preceding section that residual stress significantly affects the fatigue properties of steel, we analyzed the residual stress of various parts of rail in order to clarify its behavior. It is reported that the initial residual stress of rails will change after installation by the passage of wheels.[9] Although this should also be taken into our consideration of the effect of residual stress on rail, we started with measurement of residual stress generated during rail manufacture.

From a few residual stress measuring methods, we adopted the so-called saw cut method as the simplest one. According to this method, strain gauges are attached to various parts of rail surface, and after cutting the rail to approximately 5~7 mm thickness × 25 mm width × 50 mm length the residual stress is calculated from the strain change before and after the saw cutting using the following equation.

$$\sigma = \frac{E}{1-\nu^2}(\varepsilon_l + \nu\varepsilon_t)$$

Here, E : 2.06×10^5 MPa

ν : 0.3

ε_l, ε_t : Rail longitudinal and transverse strains

Fig. 18 indicates residual stress measuring points on rail surface and sawing sections. Initially, strain gauges are attached to the entire surfaces of the rail, and again after sawing the rail longitudinally to the sawn cross-section. The cross-section is then further sawed into smaller section. The gauge readings after the first sawing and those after the second sawing are added to obtain the total amount of strain. Although the accuracy level of this method is somewhat low, we adopted the method to find approximate amount of stress.

First, strain change was measured at some points in the longitudinal direction of rail. As a typical example the case of the ordinary carbon rail is shown in Fig. 19. Strain measurement was carried out on a rail of 12 m in length at 4 equidistant points, the first and the last points each being located 1.5 m in from the rail ends. Nearly

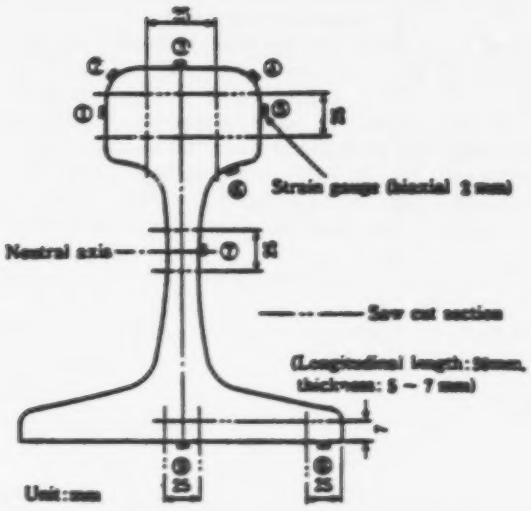


Fig. 18 Residual stress measuring points

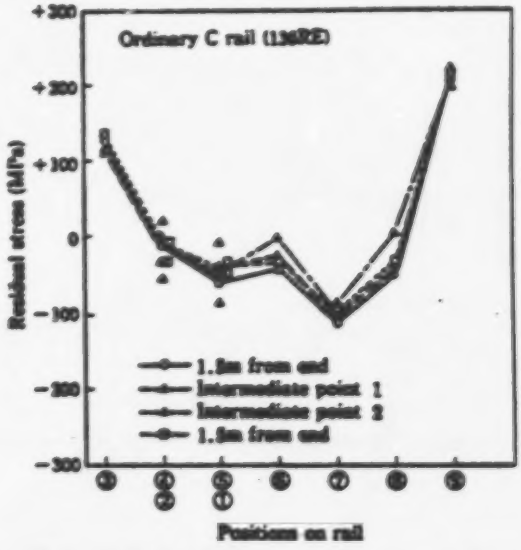


Fig. 19 Residual stress at positions on rail

the same amount of residual stress was indicated at all measuring points, and hence the residual stress level over the total length of the rail except both end portions can be regarded as constant. In addition, it was ascertained that the original residual stress could be maintained even if the sample rail is cut to a minimum of 1 m.

The manufacturing process where such residual stress is generated in the rail is indicated in Fig. 20. Namely, the amount of residual stress is different at each point between before and after straightening, and it is evident that the final residual stress is determined by straightening. The stress pattern which has tensile residual stress in head and base is observed generally in as-hot-rolled rails, and is independent of rail size and strength level.

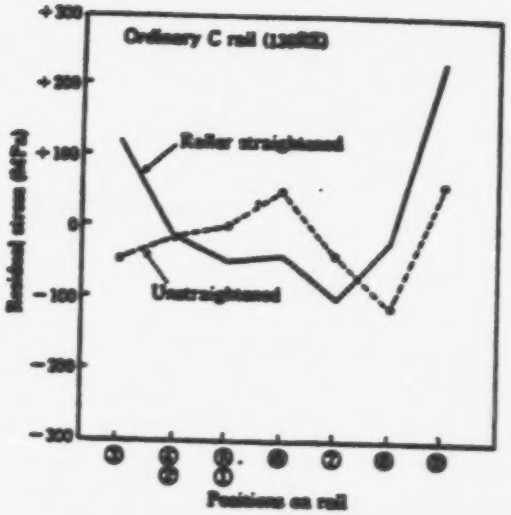


Fig. 20 Changes in residual stress by rail straightening

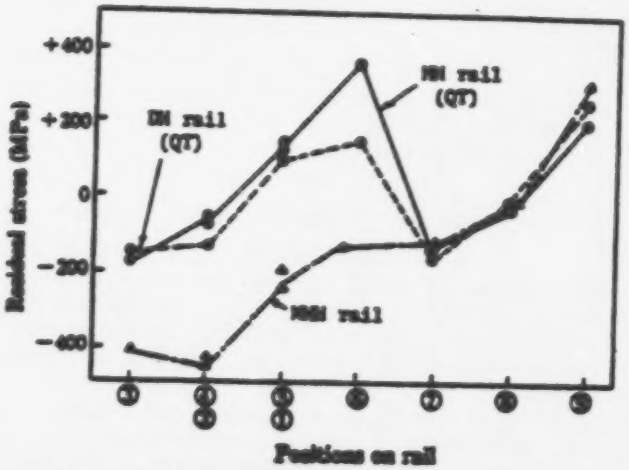


Fig. 21 Residual stress distribution of heat-treated rails

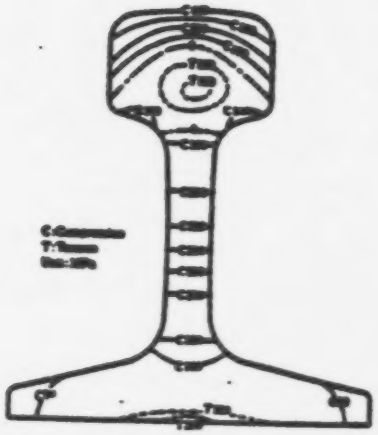


Fig. 22 Residual stress distribution of the heat-treated rail (NHH)

In contrast, however, heat-treated rails show a completely different stress pattern, as indicated in Fig. 21 This is because heat-treated rails are manufactured by heat treating roller-straightened rails followed by press-straightening. A large compressive residual stress remaining in the rail head is the characteristic of heat-treated rails. In the web and base of such rails, however, because they are not heat-treated, the residual stress distribution is the same as that generated by straightening in as-hot-rolled rail.

The magnitude of compressive residual stress in rail head differs with the heat treating condition, and is greater in head surface of the stock quenched rail (NHH) than in that of the quench and tempered rail (HH). Illustrated in Fig. 22 is a typical residual stress distribution measured on a cross section of NHH rail. How this compressive residual stress is related to actual rail failure is not clear, and awaits further study. However, this compressive residual stress is also known to be fairly effective in retarding propagation of crack, as will be discussed in the following section, so is an important determinant of rail characteristics.

Table 2 Chemical compositions and mechanical properties of test rail steels

Type	Chemical composition (%)								YS (MPa)	TS (MPa)	El (%)	RA (%)	Hv (10 kg)	σ_{cr} (MPa)	Remarks
	C	Si	Mn	P	S	Cr	Mo	Others							
C	0.75	0.23	0.97	0.010	0.005				802	902	16	30.6	282	385	
MC	0.84	0.27	1.43	0.021	0.006	1.01		0.05V	824	1,013	19	35.8	296	454	
MS	0.72	0.92	1.27	0.022	0.010				805	1,000	16	31.7	288	434	Hot-rolled, pearlite
CV	0.74	0.29	1.20	0.021	0.011	0.79		0.12V	859	1,110	10	22.8	327	502	
CVC	0.77	0.29	1.24	0.010	0.004	0.88		0.14V	700	1,220	11	23.6	280	502	
CRM	0.76	0.15	0.85	0.014	0.006	0.89	0.13		656	1,125	10	20.3	305	503	
LC	0.38	0.23	1.20	0.010	0.008	1.17	0.20	0.07V B	812	1,080	17	28.9	324	488	Hot-rolled, bain...

4.3 Fatigue Crack Propagation Rate in Rail Steels[20]

It is well known that the following equation holds good for the calculation of fatigue crack propagation rate except for the initial period of cracking and near the final fracture.

$$\frac{da}{dN}=C(\Delta K)^m$$

Here, a : Crack length, N : Number of cycles, ΔK : Stress intensity factor differential, and C, m : Material constants. Using this equation, the fatigue crack propagation rates of different rail steels were obtained.

Table 2 contains metallurgical properties of rail steels, and the specimens were cut out of the rail web, as shown in Fig. 23. The test was conducted by applying a pulsating tension mode with a stress ratio of $R=0$ at ambient temperature. Fig. 24 shows the test results, indicating that the crack propagation rate varies substantially with each specimen. Fig. 25, on the other hand, represents the crack propagation rates obtained using specimens cut out of the same rail and stress-relief annealed at 520°C for 30 minutes. As compared to Fig. 24 difference in crack propagation rate among rail steels is narrowed down, and further its level is shifted toward the faster side, which demonstrates that the residual stress

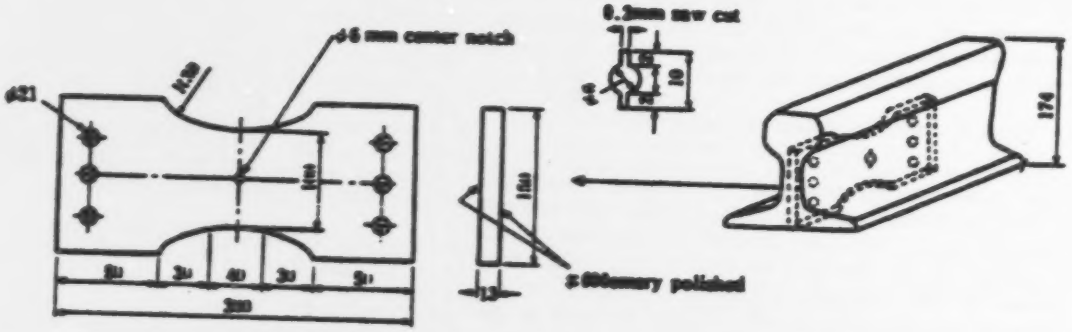


Fig. 23 Specimen for measuring crack propagation rate

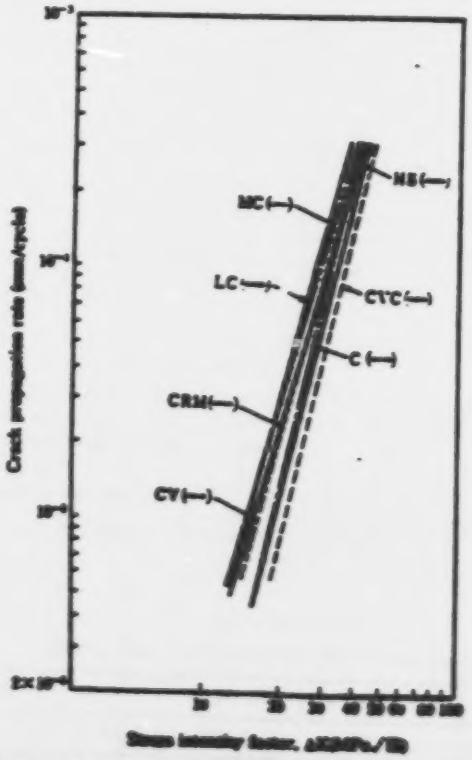


Fig. 24 Fatigue crack propagation rates of various rail steels

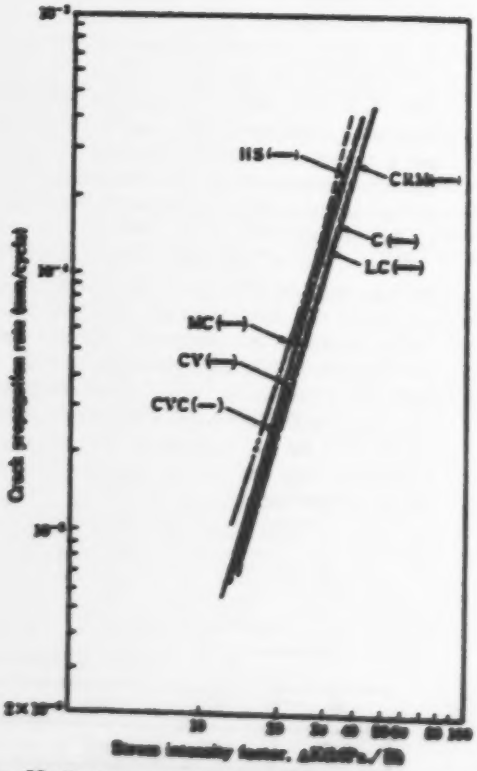


Fig. 25 Fatigue crack propagation rates of various rail steels (annealed at 520°C for 30 min.)

influences the crack propagation rate. In fact, the residual stress in this test noticeably differed before and after annealing.

Thus, it can be concluded that although the fatigue crack propagation rate of rail steel is scarcely affected by material strength or microstructure, it is definitely affected by residual stress. Considering that stress in the longitudinal direction of rail is necessary for propagation of crack which will lead to rail fracture,[22] compressive residual stress can be expected to delay the propagation of crack. Furthermore, because the residual stress gradually diminishes with the propagation of crack, it is not necessary to consider the effect of internal tensile residual stress as long as the crack develops from the compression side, and hence the compressive residual stress will not affect the K value at the final fracture. As was discussed earlier, however, this residual stress can be considered to be changed especially in the rail head due to installation condition and by the passage of wheels, further detailed study is necessary to clarify the actual effect of residual stress in consideration of these factors.

5. Metallurgical Properties of NHH Rail[23]

5.1 Base Material

As it has been mentioned in the foregoing sections that high strength fine pearlitic structure would substantially improve various rail characteristics, and the metallurgical properties of the new rail steel (NHH) have also been treated in these sections, a general description of the characteristic properties of NHH rail will be given in the following section.

Table 3 presents chemical compositions and the mechanical properties of NHH rail. The chemical compositions when compared to those of the ordinary carbon rail steel do not differ much except for slightly higher carbon content. The increase of carbon content remarkably improves both wear-resistance and the mechanical properties of rail head after heat treatment. Moreover, while the rail head has a tensile strength of over 1,200 MPa, the ductility of the rail is good, which is because the effective grain size of the pearlitic structure by rehoening keeps No. 7.5~8.5 as the average.[23]

Photo 4 shows the heat-treated pattern of a rail head section and the microstructure 5 mm below the central surface of rail head showing fine pearlitic structure.

The hardness distribution in the rail head in Fig. 26 shows that the highest point reaching Hv 380~400 exists in the surface layer, which, however, progressively decreases inward. Such hardness on the surface layer cannot be attained by full heating of rail section, but the heat conduction into the rail web by gradient heating works as an important factor.

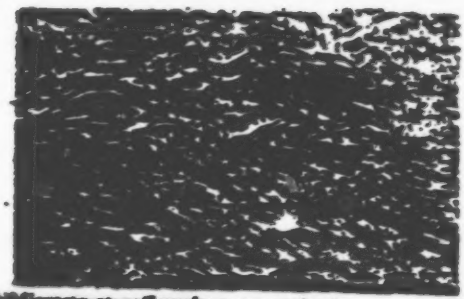


Photo 4 Metallurgical structures of head section of NHH rail after heat treatment

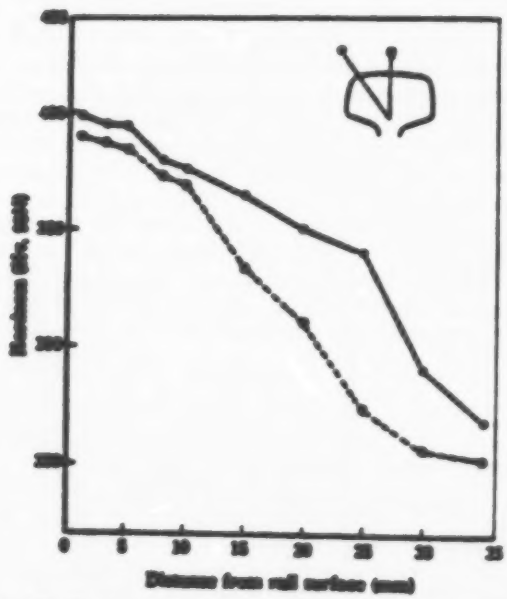


Fig. 26 Hardness distribution of head section of NHH rail

Table 3 Chemical compositions and mechanical properties of rail head (NHH) [%]

C	Si	Mn	P	S	0.2 PS (MPa)	TS (MPa)	El (%)	RA (%)	H_B
0.78	0.23	0.88	0.014	0.005	880	1,300	15.7	38.3	

5.2 Weldability

Nowadays rails are usually welded into long strings to extend rail life and ease railway maintenance. The weldability of high strength rail steels, i.e., mechanical properties of weld zone and welding efficiency, has become more and more important. Many high-strength steel rails have been developed by strengthening the pearlitic structure. These rails are broadly classified into two types. One is an as-rolled alloy steel rail, which is naturally cooled after hot rolling and whose high strength is given by addition of alloys. The other is a heat-treated high-carbon steel rail, which is subjected to rapid cooling after reheating of the whole section or the head of the rail.

Although all of these rails have good wear resistance, their weldability generally poses a problem. When alloy steel rails are welded, weld zones harden and become brittle because of high hardenability. For this reason, postweld heat treatment is sometimes carried out to soften hardened parts. In the case of heat-treated rails, weld zones soften from hardened parts of base-metal rails. This softening causes irregular wear and deformation of the heads of rails in service. For this reason, trials have recently been made to prevent this softening by forcedly cooling weld zones just after welding or after reheating.

Fig. 27 shows the hardness distributions at the depth of 5mm from the surface of rail head at flush butt (FB) welding joint sections of three types of rails. Fig. 28 shows the hardness distributions at running surface of MHH 50 kgN rail welded by gas pressure welding with forcedly air cooling weld zones after reheating.

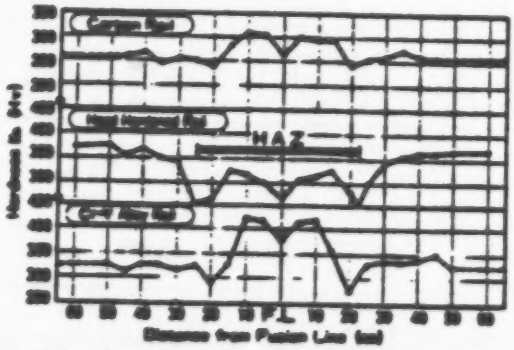


Fig. 27 Hardness distribution of weld joint sections of three types of rails. (FB welding)

These postweld heat treatments are undesirable in that they reduce welding efficiency although they improve the behavior of weld zones. Therefore, a trial was made at NKK to develop high-strength steel rails that can be welded under the same conditions as with ordinary carbon steel rail and that do not require any postweld heat treatment.

6. Weldable high-strength steel rail

To improve the performance of the weld zone of a rail, it is necessary to maintain the same pearlitic structure and strength (hardness) as those of the base metal as far as possible. For this purpose, the transformation temperature in the heat-affected zone of the rail must be proper after welding. In this case, however, the transformation temperature cannot be changed by coercively changing the cooling rate, because the cooling rate of the heat-affected zone is predetermined by rail size and welding conditions. Therefore, it is necessary to achieve an optimum transformation temperature by improving hardenability, i.e., adding alloying elements.

In this connection, addition amounts of general alloy steel rails are large and, therefore, the structure of the heat-affected zone is more or less of martensitic structure. For this reason, the amount of alloying elements added is limited, which inevitably leads to insufficient strength of the base metal of the rail. Therefore, it is necessary to compensate for the insufficiency by increasing the cooling rate after rail rolling or reheating.

The above-mentioned concept means development of new rails by heat treatment of an alloy steel to which proper amounts of alloying elements have been added.

6.1 Targets for weldable high-strength steel rails

The basic items are summarized as follows :

1. Wear resistance is improved by using steel of pearlitic structure and strengthening it. The same applies also to the improvement in fatigue failure resistance.
2. The block size is made small as far as possible from the standpoint of ductility.
3. Welding conditions must be similar to those for ordinary carbon steel rails and the hardness in the HAZ is made close to that of the hardened base metal. However, the basic structure must be pearlitic.

In consideration of these items and the results of fundamental experiments the following target values were set for the new rails to be developed : 0.2 % proof stress ≥ 880 MPa, tensile strength ≥ 1,250 MPa, reduction of area ≥ 35 %, maximum hardness of HAZ ≥ 350 Hv, and martensitic structure of HAZ ≤ 5 %.

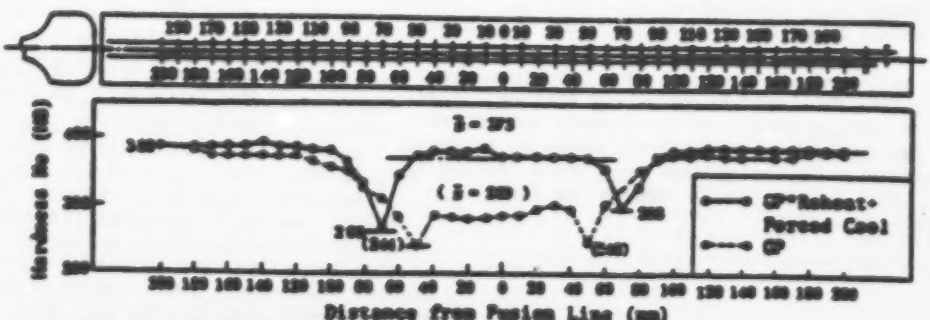


Fig. 28. Hardness distribution of weld joint section of MHH 50N rail (gas pressure welding with after heat treatment)

Then, the two chemical compositions - Si-Mn (HS Type I) and Cr-Si (HS Type II) - given in Table 2 were selected as those which meet the above-mentioned target values. Strengthening ability, transformation characteristics, ease of segregation, improvement in

Table 4 Chemical composition of weldable high-strength rail steels

Element, %	HS-Type I	HS-Type II
Carbon	0.74 to 0.80	0.72 to 0.80
Silicon	0.85 to 0.95	0.85 to 0.95
Manganese	1.10 to 1.30	0.70 to 0.85
Phosphorus	≤ 0.025	≤ 0.025
Sulphur	≤ 0.015	≤ 0.015
Chromium	-	0.45 to 0.70
Niobium	≤ 0.02	≤ 0.02

The head hardening process was selected as the heat treatment of the rail. One of the reasons is that to effectively secure the cooling rate necessary for obtaining high strength, the head of the rail is slack quenched by air from the outside by non-steady state heating of the head and also the cooling by heat conduction to the lower part of the rail is utilized at the same time. Another reason is that residual compressive stress is generated in the outer layer of the rail head when this process is employed. These residual stress can be expected to be effective in preventing the generation and propagation of cracks due to rolling contact.

6.2 MANUFACTURE OF WELDABLE HIGH-STRENGTH STEEL RAILS AND THEIR PROPERTIES

Manufacture

Based on the above-mentioned concept, rails Type I and Type II were manufactured to investigate the properties of actual rails. After refining in a 150 t BOF the rail steels of these new chemical compositions were subjected to the vacuum process in which adjustment of chemical compositions was conducted during degassing. After that, the steels were cast as ingots of approximately 7 t by the bottom pouring process. After soaking, these ingots were rolled to blooms 365 × 365 mm. Then, the bloom surface was dressed as required. After reheating, the blooms were rolled to rails of sections ARBA 136 lbs. and JRS 60 on a universal rail mill and rails were cut by a hot saw. After cooling, these rails were straightened by a roller straightener and then cut by a cold saw. After several strict inspections, the rails were subjected to the heat treatment process.

The rail head was hardened in a continuous heat treatment line developed by NSC using heating temperatures and cooling conditions previously controlled so that the above-mentioned targets could be obtained. These rails were roostraightened by a press leveler as required, and were completed through the final inspection process.

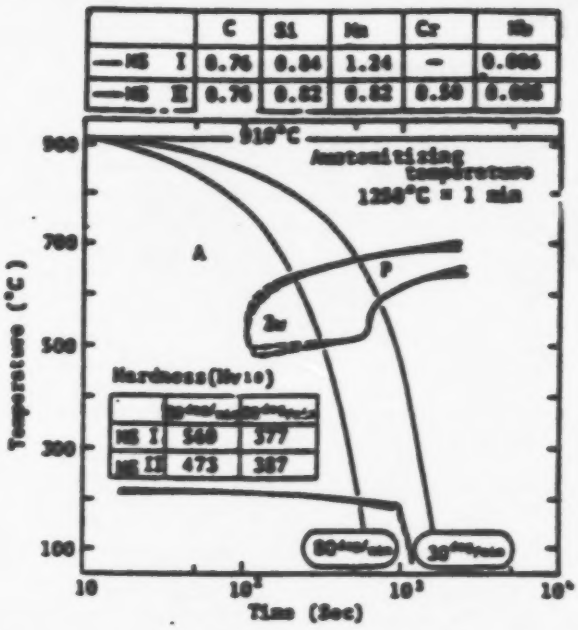


Fig. 29 CCT diagrams of HS I and II rail steels

Properties

Table 5 shows the chemical compositions and average mechanical properties of these two types of rail. Type II is somewhat superior although both s show almost the same properties in tests in the laboratory. Therefore, Type II will be mainly refe ed to in the following.

Table 5 Chemical compositions and mechanical properties of as-rolled and heat treated rail steels of HS I and HS II

	C	Si	Mn	P	S	Cr	Nb
HS I	0.76	0.84	1.24	0.023	0.009	-	0.00
HS II	0.76	0.82	0.82	0.020	0.006	0.49	0.00

Rail type	Heat treatment	0.2% proof strength	Ultimate tensile strength	Elongation	Reduction of area	Remarks
HS I	as rolled	608 MPa	1096 MPa	12 %	18 %	
	heat treated	873	1288	14	41	*
HS II	as rolled	688	1127	14	19	
	heat treated	982	1324	19	50	*

(*) Specimens (6 mm in diameter) were cut out of the locations 5 mm from the top surface of rail head.

These rails show an ultimate tensile strength of approximately 1,100 MPa in the as-rolled condition. This means that even rails before heat treatment show at least the same strength level as average alloy steel rails. There is no problem in the results of various tests, such as Drop test and Nick and Break test, conducted in accordance with the AREA Specification.

Photo 5 (a) shows the macrostructure of the head of an Type II rail after heat treatment. The black part of the head indicates a fine pearlitic structure as shown in Photo 5 (b).

Fig. 30 shows the hardness distribution in the head section. Hardness values are from to Hv on the head surface and continuously decrease toward the inside. The test results of tension test specimens (6 φ) cut out of locations 5 mm from the head surface are shown in Table 3. The reduction of area is very satisfactory, with high strength kept.

Fig. 31 shows the results of US grain size measurement of an Type II rail before and after heat treatment. For comparison, the grain size of an ordinary carbon steel rail is also shown. The structure of the Type II rail shows fine grains in each of the locations and this is remarkable especially in the head after heat treatment. This is the reason why the reduction of area is good in spite of high strength. The K_{IC} value of a specimen sampled from the head is approximately 40 MPa $\sqrt{m}$ at room temperature and deterioration due to strengthening is not recognized.

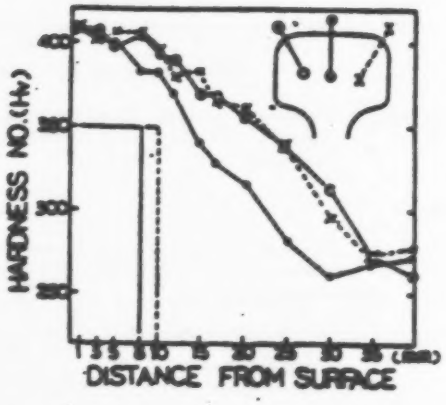
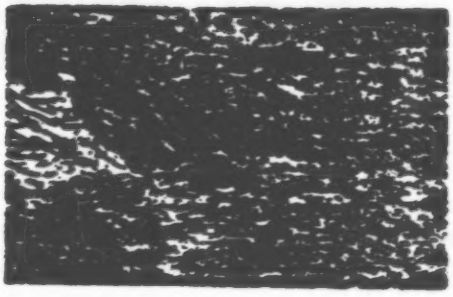


Fig. 30 Hardness distribution of rail head section of NS II

Weldability

The above-mentioned rails were welded by flash butt welding and their properties were investigated. Welding was carried out under the same conditions as with ordinary carbon steel rails, shown in Table 6, and pre- and postheating were not carried out at all. Photo 6 shows the section of the center of rails welded. The formation of martensitic structure was not observed at all. Fig. 32 shows the hardness distribution in the section of the center ; the hardness in the HAZ is kept above 320 Hv except with softening by a temperature rise to near the A_1 transformation temperature at which the pearlitic structure is destroyed. This is effective in making narrow the width of the softening zone formed by heating to the above-mentioned temperature range. In a three-point bending test with 1 meter span, the Type II rail showed a load of approximately 1.8 MN and a deflection of approximately 15 to 17 mm, thus demonstrating good weldability.

(a) Macrostructure



(b) Microstructure (5mm from top surface)

Photo 5 Metallurgical structure of head section of NSII NHH rail after heat treatment

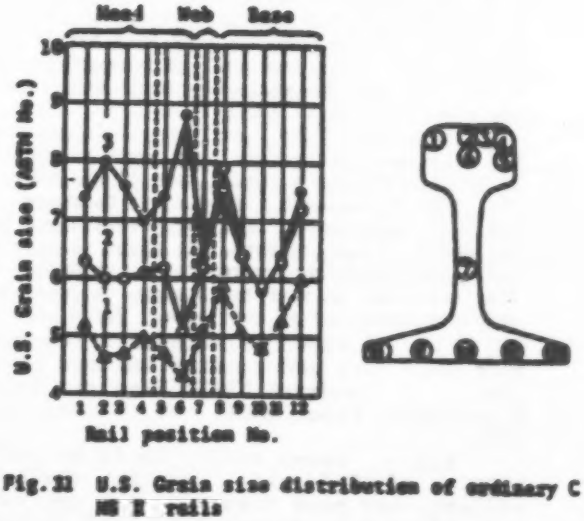


Fig. 31 U.S. Grain size distribution of ordinary C and NS II rails

1. Ordinary C rail
2. NS II rail (before heat treated)
3. NS II rail (after heat treated)

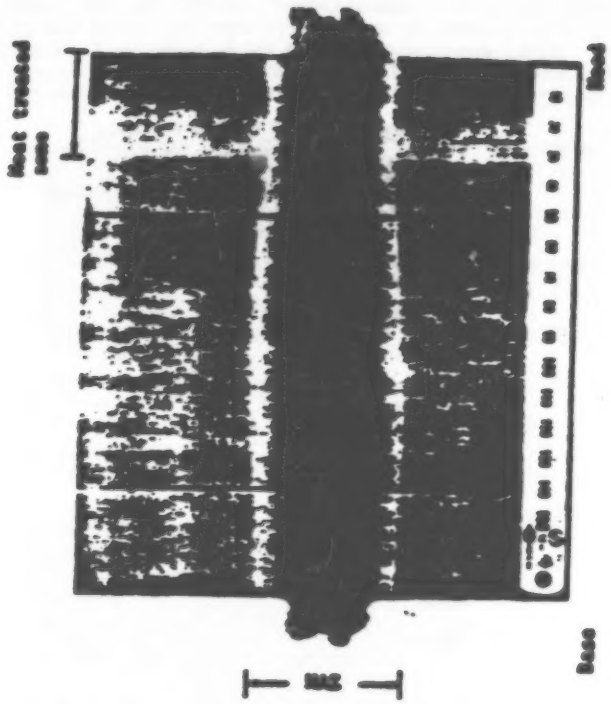


Photo 6 Macrostructure of longitudinal-vertical section of NS H rail welded by flash butt welding

SERVICE BEHAVIOR

As mentioned above, many new rails have recently been developed to improve the wear resistance and fatigue failure resistance of rails under transportation conditions of increasingly heavy load. Fig. 33 shows the average proof stress and tensile strength of so far reported high-strength rails and those developed this time. It is apparent from this figure that heat-treated rails provide high strength relatively easily and that the rails developed this time show the highest strength level.

These rails Type I and Type II, along with the NSH rail developed before them, were sent to the USA in April, 1979 for a laying test on the PAST. The rail Type II has been tested since December, 1979 in the third experiment. The test results are being presented in some reports. It might be said that this rail shows satisfactory results as expected, may, more than expected, in wear resistance, failure resistance and serviceability of weld zones. Tests were

Fig. 34 shows relationship between gage face wear rate and running surface hardness. (from J.R. Lundgren "PAST Results, Selected Highlights" Proc. AREA. vol.82 1981, pp.336-358).

Fig. shows valley depth at welded portion of NSII rails. At this flash butt welding, any heat treatment was not carried out. (from R.K. Steele 1982 PAST Engineering Conference report P.131)

Table 6 Flash butt welding condition of NS H rail

Max. current density : 30,000 A/mm²
Upset force : 40 Ton
Upset : 13 mm

Zone	No-Load Voltage	Flashing Speed	Time
Pre-heating	7.5 V	0.22mm/sec	64
Flashing	6.3	"	118
Final Flashing	7.5	0.25 ~ 1.4	10
Upsetting	7.5	-	8.5° ~

K355 Welding machine • Current

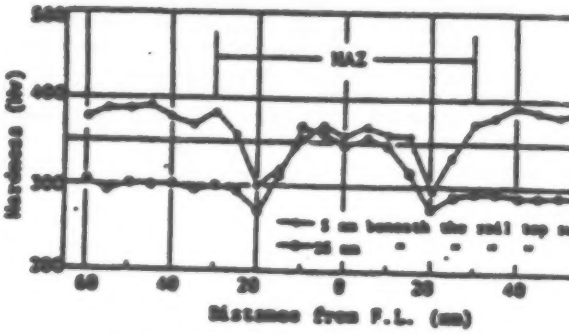


Fig.32 Hardness change on the longitudinal-vertical section of NS H rail welded by flash butt welding

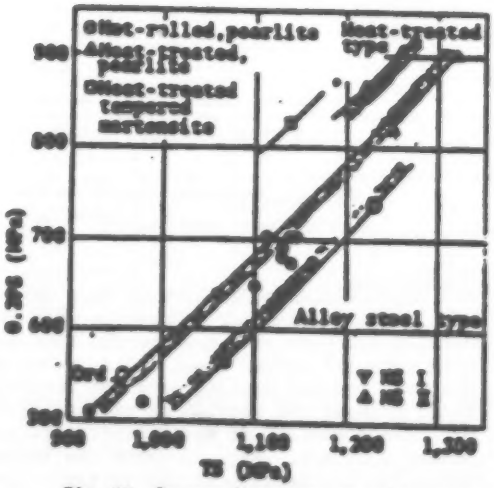


Fig.33 Strength level of rail steels

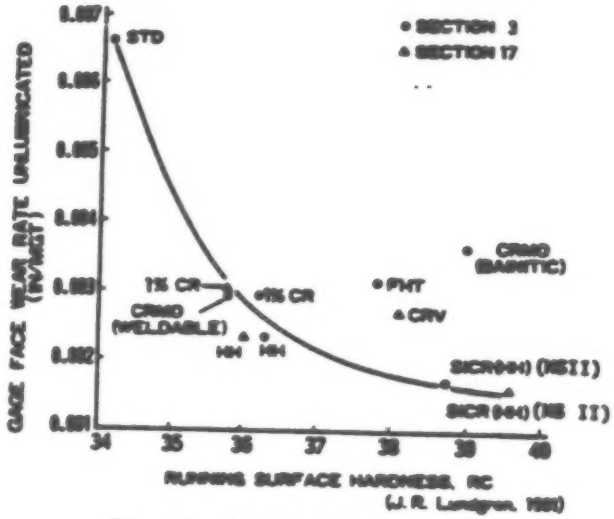


Fig. 34. Relationship between gage face war rate and running surface hardness.

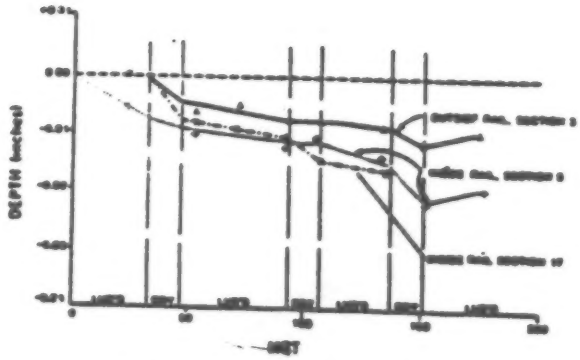


Fig. 35. SiCr [HH]/VALLEY DEPTH (HS II)

Tests were started also with the rails NHH and Type I in December, 1980 and April, 1981, respectively. Detailed comparative examinations of the service life of these rails and their metallurgical analyses will contribute to the solution of long-pending problems relating to rails, such as wear, fatigue and corrugation and these results will lead to the development of rails of better quality.

CONCLUSION

The recent trend toward heavier load or higher speed has increased the wear and fatigue failure of rails. Therefore, rails capable of withstanding this severe situation are much in demand. Some of these concrete problems were examined and material factors were clarified to find conditions to be met for the improvement of properties of steel rails. Based on the results of such examination, new rails were developed at NSC.

The results can be summarized as follows.

(1) The results of laboratory scale wear test are in general agreement with the wear behavior of rails used on mine railways abroad.

(2) Some rail failures occurring to high-speed railways were analyzed, and it was confirmed that these failures were caused by rolling contact fatigue. For laboratory simulation of this phenomenon, the RCF test was developed.

(3) As a result of the study of metallurgical factors for improving rail life by the above test methods, it was found that strengthening or hardening of rail steel with pearlitic structure will principally improve both wear-resistance and failure properties.

(4) The fatigue strength of rail is dependent not only on rail steel but also surface condition and residual stress of rail. In that sense, the heat-treated rail has excellent fatigue characteristics, and its compressive residual stress will retard the initiation and propagation rate of fatigue crack and may extend the life of rail up to fracture.

(5) These principal results are now embodied in a new rail, NHH rail, manufactured by the heat treatment of rail head. NHH rail, having the highest strength level in the world, is now being adopted for the railways in the world as a wear and failure-resistant rail.

(6) As for the weldability of rails, NSC developed a manufacturing process for head-hardening of steel rails to which alloying elements have been added to obtain improved performance and the same efficiency of weld as that of ordinary carbon steel rails at the same time.

(7) New rails NS I (Si-Mn type) and NS II (Cr-Si type) were designed as rails that meet (5) and (6) above, and rails AREA 136 lbs. and JRS 60 were manufactured on a trial basis. These rails (136 RE) are being subjected to a laying test on the FAST, USA. From the interim reports of the test, virtually satisfactory results have been obtained with the rail NS II which was tested earlier than NS I.